Exploring the Design and Use of Forecasting Groupware Applications with an Augmented Shared Calendar

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Exploring the Design and Use of Forecasting Groupware Applications with an Augmented Shared Calendar

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To Elaine, for making every day a lovely day.

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Summary

Changes in work, along with improvements in techniques to statistically model uncertainty, have resulted in a class of groupware tools able to forecast the activities and/or attentional state of their users. This thesis represents an exploration into the design, development, and use of one such system.

In this thesis, I describe the design and development of a groupware calendar system called Augur that is augmented with the ability to predict the attendance of its users. Using Bayesian networks, Augur models the uncertain problem of event attendance, drawing inferences based on the attributes of calendar events as well as a history of attendance provided by each user. This system was deployed to an academic workgroup and studied over the course of a semester. To more deeply explore the social implications of Augur and systems like it, I conducted a structured privacy analysis of Augur to examine the vulnerabilities inherent in this type of forecasting groupware system.

This thesis makes the following major contributions:

- An architecture, user interface, and probabilistic model for Augur, a groupware calendar system capable of predicting the attendance of colleagues at future events. This work also addresses the feasibility of such a system and the challenges faced when deploying it to an academic workgroup.
- An exploration of the system's use by individuals, its effects on communication within working relationships, and its effectiveness with respect to the presence of domestic calendars.
- A set of implications for the workplace social environment with the introduction of Augur. Specifically, I show how the integrity of predictions generated by Augur

can have consequences for the privacy of users and their representations through the shared calendar.

Overall, this thesis is presented as an early exploration into the potential for a new class of forecasting groupware applications. It offers guidance and lessons learned for both designers and researchers seeking to work in this area, and presents a complete calendar application as an example for building and studying such systems.

Chapter 1: Introduction

Recent research in human-computer interaction is taking advantage of predictive user models for forecasting presence and/or availability to develop novel solutions for supporting the communication and collaboration of groups. This thesis details the design, development, field study, and analysis of one such system as a means of understanding the possibilities of these new tools for improving group work and exploring their feasibility for mainstream use.

Traditional means of group coordination are being challenged by changes in the way people work. Workers in many domains now have increasingly flexible hours, often telecommute, or participate in virtual teams with varying degrees of geographic collocation. Additionally, the limited capacities of our attention and working memory [31, 72] have necessitated the development of new systems for efficiently managing the initiation of communication and potential disruptions caused by interruption. Such systems often incorporate user models and predictive algorithms borrowed from the field of intelligent systems to inform users of the future availability and/or location of colleagues. This information can serve as an additional resource when integrated with existing coordination tools such as the telephone, email, shared electronic calendars, and instant messaging clients.

To date, researchers have built a number of experimental systems to address different aspects of the communication and coordination problems described above, such as assessing availability [27, 46], supporting opportunistic meetings [2], and maintaining awareness of presence [6]. Considerable effort has been spent in developing these systems and honing the user models and predictive algorithms they employ. They have only begun to examine the implications such systems have on the work practices of the environments in which they are deployed. In addition, workplace social characteristics such as regulation of privacy and impression management [32] require study within the contexts of these systems.

The goal of this thesis is to describe the design, development, and study of a single system, called Augur, that augments the traditional groupware calendar system with forecasts about colleague presence. Through this work, I hope to inform the design and deployment of future forecasting tools as well as add to our field's understanding of the use of intelligent user interfaces in everyday applications.

The remainder of this chapter will define the terms and research areas necessary to a thorough understanding of the thesis. These definitions will contribute to the development of the motivating thesis statement, the contributions offered by the thesis, and a summary of how the results described in the rest of this dissertation will validate the claims inherent in the thesis statement.

1.1. Definitions

1.1.1. Groupware

Groupware is defined as the broad class of software applications that enable a group of coworkers to simultaneously work on a common project or goal. Such applications can support real-time collaboration, such as video conferencing tools, or asynchronous collaboration, such as email and shared calendars. They may provide support for general tasks such as communication and coordination, or provide specific functions related to a project in the group's area of expertise.

Groupware is the product of research and design activity in the realm of computer-supported cooperative work (CSCW), a field whose origins exist in user interface design but is grounded in the study of the interface as it pertains to work environments [35]. While CSCW research is most often associated with and influenced by the field of human-computer interaction (HCI), it also relies heavily upon the disciplines of anthropology, social psychology, and organizational behavior. Dix [20] provided a useful framework for examining groupware (Figure 1-1).

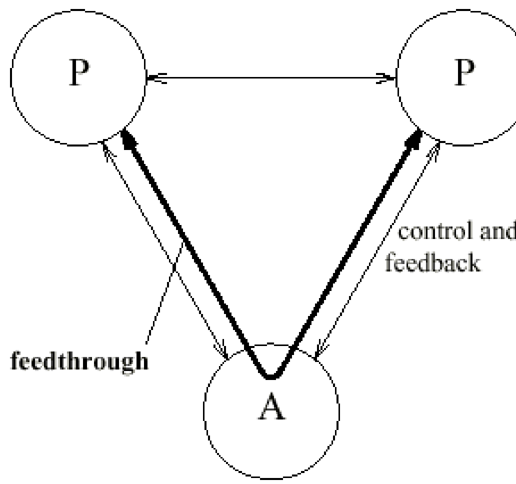

Figure 1-1: Dix's framework for CSCW and groupware systems.

Within this framework we observe two participants (denoted by the letter P) and a shared computerized artifact (denoted by the letter A). While the participants can communicate directly, as illustrated by the arc between them, they are also able to observe and control the shared artifact in the interest of accomplishing some work, shown by the arcs from each participant to the artifact. Actions by one participant upon the artifact may be observed by the other participant, making communication through the artifact, or *feedthrough*, possible.

1.1.2. Communication: informal and formal

Note that the communication facilitated by the artifact may take many forms. Groupware tools may afford direct communication between participants in a number of ways, such as presentations, formal meetings, or courses. In addition, groupware can assist in technologically-mediated communication via phone, email, instant messaging, and videoconferencing.

Another distinct class of information exchange is *informal communication*. A basic definition by Whittaker [101] describes informal communication as brief, unplanned face-to-face meetings. These meetings are typically dyadic, lack formal greetings or closings, and tend to be interruptive in nature. Informal communication has been the subject of much work in the HCI and CSCW literature for well over a decade, and has been shown to be vital to work, making up anywhere from 30-80% of time spent working in various studies [84, 91].

In the context of this thesis, Whittaker's definition of informal communication, though succinct, is somewhat limited. The distinction between formal and informal communication is more akin to a continuum of various attributes, such as the degree of advance planning, the extent to which there is a preset agenda, etc [61]. In interviewing and observing participants, rather than drawing a distinction between purely unplanned or spontaneous meetings and formal meetings that are planned well in advance, I have attempted to portray a more nuanced view of the communication that is actually occurring.

Like Whittaker, I am predominantly treating informal communication as a face-to-face phenomenon. However, I am also aware that other media such as email [22] and instant messaging [78] serve many of the same purposes. Since the landscape for informal interactions has been changed by computer-mediated communication (CMC), the qualitative results presented in Chapter 4 touch on how these exchanges fit into the greater communication environment that also includes planned communications and exchanges facilitated by CMC tools.

1.1.3. Groupware calendar systems

Groupware calendar systems (GCSs) are defined as electronic calendar information that is shared over a network. They are one of the oldest groupware applications, appearing in Axxa's System 90 and IBM's System/34 as part of office automation systems in the late 70's [41]. Personal use of electronic calendars was studied extensively starting in the early 1980's and continuing into the 1990's [57, 59, 85]. Study of the social context and adoption issues surrounding GCSs was initiated by Ehrlich [23]and Grudin [39], continuing into later work by Palen [81]. Today, GCSs support a variety of activities including scheduling, reminding, and determination of colleague availability. Standard features include meeting scheduling/invitation capabilities; the ability to edit, recur, and set reminders for events; daily, weekly, and monthly overviews of schedules; and the ability to view the calendars of colleagues.

Returning to Dix's framework for groupware, recall that the actions of one participant on an artifact can be observed by another participant through the artifact and thus enable communication. With electronic shared calendars, more information can be communicated than a simple schedule. Users can potentially infer such things as current projects, social networks, and broader patterns of activity. Thus, the calendar presents a limited representation of a particular user to those browsing her calendar. For coworkers who rarely have face-to-face contact with one another, the calendar potentially represents them for the purposes of any tasks it facilitates, making management of this representation an important task (see Chapter 5). The framework presented earlier in Figure 1-1 can now be applied to the GCS in Figure 1-2, below.

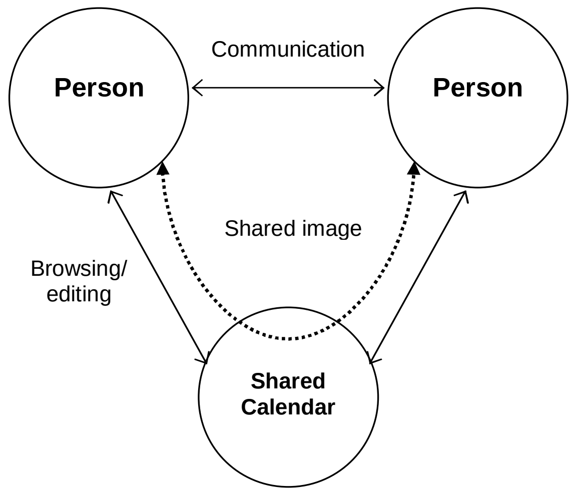

Figure 1-2: Groupware calendar systems in the CSCW framework.

By browsing the calendars of colleagues, users can make estimates of their locations and availability. By scheduling appointments and sharing this information, users control the calendar artifact and enable browsing.

Adopters of electronic calendars often do not maintain their calendars with others in mind, be they colleagues or computational agents [81]. Such individual use is often at odds with the goals of colleagues who may be attempting to assess availability or activity through viewing others' calendars. This is especially true if those adopters were previously accustomed to using a personal, unshared electronic or paper calendar. Also, if the calendar is suitably detailed for its owner's needs, it may be a burden for her to diligently maintain a more complete calendar than necessary.

This lack of detail can confound estimates of availability generated by colleagues and agents alike. An unpublished study at a large computer company found that calendars were often cluttered with recurring appointments that were no longer attended (Erin Bradner, personal communication), while my own studies with academic workgroups have shown that events were attended between 52% and 63% of the time. In the interest of making calendars more useful tools, I have pursued the application of intelligent user interfaces to provide informed predictions about users' true schedules.

1.1.4. Intelligent user interfaces

Intelligent user interfaces are defined by Maybury as "human-machine interfaces that aim to improve the efficiency, effectiveness, and naturalness of human-machine interaction by representing, reasoning, and acting on models of the user, domain, task, discourse, and media." [69] Whereas HCI often uses models to drive designs [11, 55, 77], intelligent user interfaces implement these models using representations derived or borrowed from the field of intelligent systems. Since this process has an inherent degree of uncertainty, an appropriate representation must be chosen that can encode this uncertainty and make probabilistic predictions based on the information available.

In this thesis, I focus on the development of models to represent a human's mental evaluation of possible attendance at future scheduled events, implementing an intelligent component that offers its predictions as a supplement to the user's decision-making process. Chapter 3 discusses the choice of representation used for these models, as well as the process used to them and a technique for improving the models over time through learning.

1.1.5. Presence and availability forecasting

I argue that to better support the communication and coordination needs of a group of coworkers, it is possible to exploit patterns of activity or state in individuals to predict future activities or states. I focus in particular on those systems that seek to predict future availability or presence of colleagues. *Availability* is simply the accessibility or receptiveness of a person to incoming notifications or interruptions, while *presence* is the existence of a person at a given place and time. Such systems follow the aforementioned definition of intelligent user interfaces by representing, reasoning, and acting on user models of presence and availability. First, there is some type of *sensing* that occurs to gather the evidence needed to make a determination of presence or availability. This sensing may monitor the physical environment, such as noise levels or location tracking, or it may indirectly sense activity by tracking use of desktop applications or mobile devices. Next, this sensed information is interpreted by a *reasoning* system that generates predictions from an internal representation of the user or users. Finally, the information is acted upon by *presenting* it to the group via interface augmentations on existing work tools or via separate dedicated applications. In this thesis, I focus on a system that uses calendar information and event attendance logs as its input, Bayesian networks as its reasoning engines, and an augmented shared calendar as its presentation medium.

Synthesizing the previous definitions, I have illustrated that while GCSs are designed to support tasks such as informal communication, scheduling, and organizational learning, they can be compromised by a combination of increasingly flexible schedules and inadequate maintenance of the calendar artifact. My solution is to add an intelligent interface that provides forecasting capabilities to the GCS so that colleagues are better able to determine the presence of one another at future events. However, this solution then creates additional effects on the attitudes of the group.

1.1.6. Privacy analysis

Systems that involve the sensing of personal information, whether it is activity, schedule information, or location, carry with them a potential to violate the privacy of their users. Researchers have developed several methods to systematically analyze system designs to identify where potential violations may occur, and to guide the design and implementation of solutions that diminish or altogether eliminate this potential [10, 62]. These methods can be purely heuristic techniques that allow designers to rate their systems along a range of privacy-related dimensions, or structured methods that perform a more rigorous treatment of the goals, architecture, or policies defined by the system. In this thesis I present a structured privacy analysis of a forecasting groupware calendar as a means of exploring potential privacy vulnerabilities inherent in forecasting groupware applications.

1.2. Thesis statement

Given the overview and definitions just presented, I arrive at the following thesis statement:

A groupware calendar system augmented with predictive models of user attendance will enhance calendar-based practices, and evaluation of this system will lend insights about the effects of the broader class of forecasting groupware on communication and social factors.

The original motivations for this work were primarily to improve communication and coordination of workgroups through the application of predictive models of user attendance. Through these predictions, the shared knowledge colleagues had of one another's schedules would increase, allowing for more effective initiation of communication.

The quantitative and qualitative results I present in this thesis show effects on the calendar-based practices of users, such as communication, schedule maintenance, and impression management. The results also show, however, that it is difficult to definitively claim benefits for users of the system over the traditional GCS. First, as I describe in Chapter 4, the system performed a supplementary role within the context of all the existing communication tools available to users. Therefore, while benefits to use were reported, these instances were too sparse to claim significant improvements. Second, other uses occurred that concerned maintaining privacy as well as an accurate representation through the calendar. As I note in Chapter 6, these kinds of use could outweigh the benefits of forecasting groupware if proper controls are not designed into the interface.

Chapters 4 and 5 illustrate how the Augur system served as a test-bed for exploring social factors such as privacy and impression management. Given the novelty of systems that provide forecasts of presence and/or availability, this exploration is an important first step in uncovering the issues and challenges that must be addressed in future systems. In this thesis I present results that show how the interaction of domestic and work calendars, the use of predictive information by different parties, and the inaccuracies inherent in uncertain models of user activity all play a role in the overall effectiveness of predictive calendars.

1.3. Overview of contributions

Overall, the desired impact of this thesis is to contribute to the understanding of systems that forecast presence and availability as a means of supporting group work. This class of systems is relatively new, and to date research on such systems has focused primarily on system-building and the improvement of representations, reasoning algorithms, and overall predictive accuracy. This thesis adds a perspective on how these systems influence the environments in which they are deployed with respect to effects on user attitudes toward privacy and existing communication and coordination practices. Designers and researchers should be able to use this document to inform work on similar systems with respect to expected uses, accuracy, and effects on the workplace social environment. This work also opens new research directions for improving the reliability of similar systems, for implementing privacy-enhancing designs, and for improving control over impression and shared representation.

1.3.1. Design and construction of an Augmented GCS

I detail the creation and evolution of Augur, an augmented groupware calendar system. I previously discussed the challenges of traditional calendar systems in terms of how they fulfill their roles as groupware tools. By employing a user-centered approach, I present an architecture and user interface design for a new kind of GCS that includes a learning Bayesian network model for determining the attendance of coworkers at future events. This system allows a user to see which colleagues have scheduled the same events as him, as well as their likelihood of attending those events. The feasibility of this design is supported by several pilot studies within a small workgroup. Later, a larger-scale study provided a more rigorous and realistic evaluation of the architecture. This study revealed a number of design challenges that should be addressed by future systems with respect to obtaining adequate training data, interpreting calendar descriptions, and supporting privacy management through the interface. As part of these contributions, I outline lessons learned from the field study and suggest improvements to be made in order for applications like Augur to achieve mainstream use.

1.3.2. Effects of Augmented GCS on practices

As detailed later in Chapter 2, few research efforts have been devoted to date on the effects of forecasting groupware with respect to how communication/coordination practices change, what types of uses develop, and how different users and user relationships benefit as a result of the deployment of these tools. In this thesis, I describe how such an application affects the practices of an academic workgroup of approximately 60 people. Using both quantitative and qualitative data collection, I detail how Augur was employed by study participants, what changes it effected in both communication and calendaring practices, and how the goals supported by Augur meshed with the goals of both work-related and domestic scheduling practices. Results show that while Augur served primarily as a support application when existing practices failed, its predictive features supported atypical uses for the traditional GCS, including diagnosis of predictive features, confirmation of external image, and browsing behaviors facilitated by event matching. Additionally, Augur supported common calendar uses such as reminding, finding, and scheduling. I also detail how Augur was used across classes of working relationships, observing that both close colleagues and less close colleagues with little awareness of one another's schedules made use of the system. These relationships are classified along dimensions that include collocation, meeting frequency, meeting formality, and schedule knowledge. Lastly, I note that there is still work to be done in terms of reconciling work calendars with the different goals and practices surrounding domestic calendars.

1.3.3. Social implications of forecasting presence and availability

Lastly, I detail the implications of Augur on social aspects of the workplace, focusing particularly on privacy. As stated earlier, groupware systems present an interesting challenge with respect to privacy. I present field study results that detail privacy concerns from several perspectives. First, I report results that mirror past studies of traditional GCS use, such as omission, obfuscation, and defensive scheduling. Next, I outline how machine-generated predictions with inherent uncertainty led to concerns about misrepresentation and disclosure of third parties due to automated event matching. I then present a structured analysis of Augur that outlines potential vulnerabilities and confirms these concerns via a classroom study. Lastly, I describe how these results have implications beyond Augur to the broader class of groupware applications that provide presence and/or availability forecasting capabilities.

1.4. Thesis overview

In the following chapter, I describe relevant work in the area of groupware that forecasts presence and availability. I also discuss ethnographic research in groupware calendar systems and informal communication to further motivate the thesis. In Chapter

3, I detail the design, implementation, and iteration of a group calendar system called Augur intended to predict the attendance of its users and share these predictions among the workgroup. In Chapter 4, I present the results of a field study examining the use of Augur among members of an academic department. This study evaluated both quantitative predictions of attendance and generated qualitative results about the use of the system among participants and participant relationships. Chapter 5 presents a structured privacy analysis of Augur and identifies potential vulnerabilities that have relevance to other forecasting groupware systems. Chapter 6 concludes the thesis by recounting lessons learned from the design and study of Augur and outlining future directions for this work.

Chapter 2: Background

In this chapter, I will first establish the changes in work and our understanding of it that have led to recent advances in forecasting groupware. Next, I will provide an overview of workplace communication with emphasis on groupware calendars before moving to recent influential work in forecasting presence and availability, and describe how this thesis builds on that body of work through its approach to system design and its evaluative focus.

2.1. Workplace communication and coordination

The development of groupware that forecasts presence and/or availability is a reflection of the ways in which researchers have come to understand work in recent years. Technology has transformed work by distributing, mediating, and coordinating people. In addition, we have come to better understand the practices that comprise work, even in more conventional work settings. The processes by which people communicate both formally and informally, the recurring patterns of activity, or rhythms, which people establish in the workplace, and the ways in which people make sense of the events that happen around them all play a role in the need for better tools to support communication, coordination, and awareness.

2.1.1. The distribution of work

Communication technology has allowed work to be conducted across increasingly wider spans of space and time. Perhaps the most prevalent example of this trend is the rise of virtual teams [8] in the past 10 years. The presence of distributed, often global workforces, the need to bring together diverse groups of experts, and the use of telecommuting to manage work and domestic concerns have all resulted in a greater need to coordinate through technology, and in turn technology has evolved to try and meet these needs. Email, instant messaging, cell phones (including i-mode and SMS), and groupware scheduling tools are just some of the technologies available to mobile workers. Such distribution, however, can vary along several different dimensions. Coworkers may be distributed in time such that asynchronous interaction is favored. Group work may span geographic distance, organizational distance in terms of functional boundaries, or cultural distance in terms of either localized workplace cultures or broader organizational and national cultures.

In another sense, even traditional, collocated work can benefit from the introduction of technology that facilitates coordination. Though not geographically dispersed, workgroups often experience a high degree of local mobility [9] that introduces the same kinds of difficulties inherent in the distributed work of virtual or geographically separated workers. Workers may be temporally distributed by this mobility and find themselves spanning multiple functional, even cultural areas of an organization. Kraut *et al.* found that managers they observed were out of their offices over 50% of the time [61]. Further, Bellotti and Bly observed that “mobility propagates further mobility”, meaning that the absence of one worker in his office often resulted in other workers leaving their own offices to find him. While their study was conducted for a single product design team, their findings echo those found in earlier work on time usage by managers [84, 91] who were often not in their offices when participating in informal meetings with colleagues.

Within the context of this thesis, it is important to see that the emergence of group tools endowed with the ability to forecast future states is less a response to new work practices than an application of new technology and behavioral understanding. While scenarios can certainly be created for the application of forecasting technology to various classes of virtual teams, the combined application of new sensing technologies, machine learning, and new understandings of the behaviors surrounding work are intended to impact the broader class of traditional workgroups.

2.1.2. Informal communication in the workplace

2.1.2.1. The importance of informal communication

In the conduct of actual group work, numerous studies have demonstrated the importance of informal communication. An early use of time study by Mintzberg [73] on CEOs showed that 14% of their day was spent in unscheduled meetings. Sproull [91] showed that the attention of observed managers was most often engaged by unplanned, oral, local communications. Panko [84] later observed that managers spent over half of each day in face-to-face communication, with employees in other roles (administrators, professionals) spending at least a quarter of their time doing so. In addition, roughly 80% of meetings attended by managers were devoid of agenda or advance scheduling. Whittaker later noted in an observational study of two mobile professionals that informal communications accounted for 31% of office activity.

It should be noted here that the degree of informal communication varies with a number of factors. First, job description implies a certain need for communication that may be higher for managers and lower for subordinates. The large percentage of time spent by managers communicating informally in Panko's study demonstrates this effect. In addition, informal communication drops off substantially with increased distance between colleagues [104]. Later in this chapter I will discuss how technology, especially group forecasting tools, is seeking to improve the amount of communication that takes place between colleagues by both increasing the number of communication channels available and improving the success rate of existing channels.

2.1.2.2. Describing informal communication

As described earlier in Chapter 1, informal communication can be broadly defined as brief, unplanned, face-to-face meetings. Perhaps the most thorough treatment of the nature of informal communication is provided by Kraut *et al*. [61] They describe workplace communication as occurring along a continuous dimension of formality described by such properties as advance scheduling, preset agenda and participants, and level of interactivity (Figure 2-1). Whereas formal communication focuses on the execution of routine transactions, informal communication serves to let workers manage uncertainty and novel situations. Further, Whittaker describes informal communications as somewhat interruptive in nature, lacking formal openings and closings associated with more lengthy, formal interactions [101]. Informal communications were often not the result of random encounters, but occurred when people made deliberate trips to coworkers' offices with the intent of a face-to-face chat.

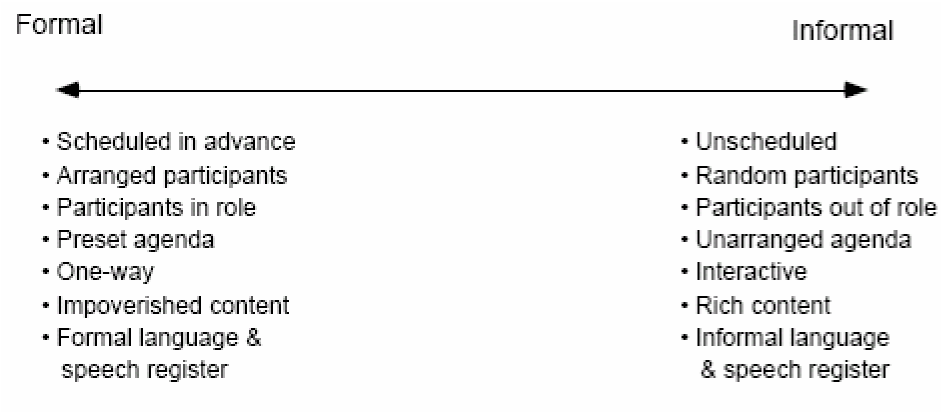

Figure 2-1: Attributes of formal and informal communication [61].

In the greater scheme of work, described in frameworks by Hackman [42] and McGrath [71], Kraut *et al*. observe that informal communication serves to assist in a variety of tasks, such as production, group maintenance, and member support, often some or all of these tasks at once. Coworkers may be simply getting a particular job done, they may be organizing resources or orienting new members, or they may be strengthening social bonds. In Chapter 4, I will describe how Augur performed in supporting these tasks during a field study.

2.1.2.3. Special case: "Ambushing"

A special case of informal communication that motivated my first forecasting groupware calendar is termed "ambushing". Simply stated, ambushing is the practice of waiting for a colleague to become present at a particular location in the interest of meeting with him. The location is known in advance, and the time at which the colleague will appear is typically not. Although the terms are used interchangeably in the literature, I distinguish this practice from "waylaying", where co-workers wait for opportunities to catch an individual at his desk [15, 100].

2.1.3. Supporting distributed work: Awareness and attention

Mobility propagates further mobility, causing informal communication and collaboration to suffer due to increased costs of initiation. Tied in to this mobility is a reduced awareness of current work and interests, less social bonding, and an inability to coordinate. Communication practices can be seen as dependent on several traits that are intrinsic to each worker. A worker's *awareness* of her colleagues, both in terms of where they are and what they are doing, is a key factor in determining how well she is able to locate them when necessary. In addition, her *attention* is a limited resource that affects her own receptiveness to any attempt to communicate with her, and in turn constrains the available cognitive resources she has to interact with her colleagues.

2.1.3.1. Attention

While the work described in this thesis does not attempt to further the emergent area of attention-sensitive interfaces, it is important to briefly remark on attention here, as it is a component of the informal communication process and the subject of much work in presence and availability forecasting systems.

Norman and Shallice [79] describe attention in terms of conscious and unconscious control. The degree to which an activity is consciously performed is dependent on the activation or inhibition of schemas related to that activity. This activation is dependent on the criticality of the activity, the experience level in performing the activity, and potential interruptions that may cause other activities to inhibit the current one. Simon describes attention broadly as allocating information-processing capacity to environmental stimuli over time. This definition implies that attention as information-processing capacity is finite.

In studies of attention in the workplace, Sproull [91] observed that for managers, attention is divided among a number of functional areas such as planning, logistics, external influences, and interpersonal relationships. While attention was structured around informal interactions within the local work environment, presence in a particular location (e.g., the manager's office) was a cue to attention but not synonymous with it. In addition, interruptions were often self-imposed as attention on a particular activity decayed. Hudson's [49] experience sampling study of managers noted that managers often viewed interruptions positively, noting that for many managers, interruptions are the primary means of accomplishing work.

The results of this work have driven many researchers to design systems that can identify periods of interruptibility, often using presence or current activity as a cue. The notion that attention is a precious resource means that people will be opportunistic about the attention of others. In the case of Augur, the system is not trying to model or cater to the attentional state of the user. However, by supporting the prediction of colleague attendance at other events, it promotes awareness of opportune moments to access the attention of a colleague using presence as a cue.

2.1.3.2. Awareness

Forecasting systems like Augur build on previous work in increasing workplace awareness. By giving people access to more status information related to the work environment, awareness systems allow workers to have more informed judgments about the presence, availability, and activity of their coworkers.

For example, systems based on videoconferencing technology, such as CRUISER [26], RAVE [30], VideoWindow [61], and media spaces [12], provide a very direct sense of awareness by offering audio/video links between the offices of coworkers. While useful for allowing communication between coworkers separated by large distances, these systems were met with some resistance with respect to privacy. While some measures can be taken to alleviate these concerns, such as blurring the video based on proximity to the camera [34], "shadowing" figures from the video [51], or taking still images only [21], the systems do not permit the "plausible deniability" of presence [78] that attracts office workers to more impoverished forms of awareness. In addition, these technologies demonstrated just how much people wanted to control access to their own information while desiring easy access to others [61].

Other techniques offer location information about workgroups. Aactive badges [98] were one of the first attempts to provide continuous information to workers about the whereabouts of their colleagues. Similarly, ActiveMap [70] provided such a display as well as the ability to perform localized text and audio messaging to available colleagues. While effective for establishing the location of coworkers, these systems do not account for their current activity. In addition, badges must be worn to be effective, and users must trade some privacy to obtain the benefits of the system.

In an effort to allay privacy concerns surrounding systems that provided continuous, detailed information such as location or audio/video, a number of systems were devised to use more abstracted representations of presence or activity. For example, Portholes [21], Buxton's telepresence client [16], and Peepholes [33] all provide some 'snapshot' of a colleague's presence or activity. In the case of Portholes, the representation is a periodic still image of the office, in the others it is a graphical icon. Other work has sought to protect privacy by altering the video in media spaces [14, 51].

A good example of this trend towards abstracted awareness information and the retaining of “plausible deniability” is found in the modern instant messaging (IM) client, which provides a simple, textual means of indicating presence. This indicator is changed by either explicit user action or by an idle timer that monitors input activity on the user’s desktop machine. While observant of privacy and quite customizable under some clients, this mechanism runs the risk of providing inaccurate or insufficient information for its users, especially if it is to be used for coordinating face-to-face communication.

The Awarenex system [93] is built on top of current IM technology, and operates on both mobile and desktop devices. It also leverages many of the observations reported in [78] concerning the use of IM in coordinating impromptu social meetings and arranging face-to-face interactions. The system supports an enhancement to the status information reported by most IM “buddy lists” by also providing the last location in which a buddy was logged in and her current or next scheduled calendar appointment. The authors state that the system should “present all the awareness information to enable the user to make informed choices that the software will not be able to reliably predict”.

By including calendar information, Awarenex provides for many of the same practices as the work I present in this thesis. The predictive information built into systems like Ambush and Augur serve as potential enhancements to a system like Awarenex, especially since the system’s predictions include information that is typically not displayed in most electronic calendar views, such as recurrence and alarm information. For instance, the prediction could be used for a quick glance at a colleague’s current or future availability, while more detailed information could be displayed if requested. In addition, these predictions allow the merging of calendar information to display availability across a group.

In addition, while “ambushing” is possible in locations where video links are provided, when a colleague’s whereabouts are unobservable, users still must rely on electronic calendars. It is possible that the inherent imperfection of the intelligence underlying the Ambush and Augur prototypes described here has an indirect effect of plausible deniability.

2.1.3.3. Sensemaking

Related to the concepts of awareness and attention is the broader theory surrounding the way people make sense of the events and circumstances they perceive. When faced with novel or uncertain events, people are called upon to develop a structure that encompasses the current situation as well as possible future states in a plausible manner. More generative than interpretation, sensemaking allows people to construct understandings that persist between pairs of people (intersubjectivity) and across the organization (generic subjectivity).

With respect to attention, increased complexity and load on individuals often breeds applications or artifacts that filter this load. Consequently, the types of sense that can be made from the resulting filtered information are restricted. This process has some bearing on the elicitation of mental models, discussed in Chapter 6.

With respect to awareness, I will draw on the example of temporal work “rhythms” most recently explored by Begole *et al* [7] and Reddy/Dourish [86]. While people typically exhibit recurring patterns to their work, their coworkers, depending on their degree of copresence and interaction, will over time internalize those rhythms and use them when deciding to initiate communication. Over time these patterns can become generalized over a broader group than just pairs of individuals. Weick [99] relates this process to sensemaking:

> Interlocking routines and habituated action patterns are social constructions that allow substitutability among agents. Because they are social constructions, generic routines and habituated action patterns are often reconstructed, and reaffirmed intersubjectively…When the same people show up day ofter day at the same time and place, their activities are likely to become more mutually defined, more mutually dependent, more mutually predictable, and more subject to common understanding encoded into common language. Generic subjectivity increases. Vestiges of intersubjectivity are evident, however, in the fine-tuning and evolving of these understandings within dyads.

Efforts to visualize, model, and incorporate explicit representations of these rhythms into work are thus attempting to disseminate the constructions developed by close colleagues to a broader range of individuals.

2.2. Artifacts to support communication and coordination

In this section I will first mention the broader class of traditional support tools, and then focus on the groupware calendar system. I will then touch on some of the research systems that have been built to improve the effectiveness of groupware tools, leading up to a new class of forecasting groupware that adds predictions about the status and behaviors of workers.

2.2.1. Traditional Media and artifacts

While this thesis will primarily concern the design and evaluation of a group calendar system, the calendar is only one artifact in a wide range of tools available to workers for coordinating with one another. Email and instant messaging, the Unix `finger` tool, and post-its or printed schedules attached to doors have been used for many years, and were significant in the studies conducted for this thesis. Of course, face-to-face communication is also a frequent channel for initiating further communication.

2.2.2. Groupware calendar systems

Groupware calendar systems (GCS's) were defined in the previous chapter. In that chapter I described how the work presented in this thesis is intended to examine the calendar's role in the CSCW framework when it is augmented with additional information about the future activities of its users. Critical to the design process, however, is a thorough understanding of the functions served by calendars in the workplace, including their role in facilitating communication.

Referring back to the study of temporal rhythms as a subject of organizational sensemaking, Zerubavel [103] observes how such patterns in calendars and schedules allow coworkers to form expectations about the availability of others. Such expectations serve to facilitate future coordination and communication.

Early studies by Ehrlich found that GCS's were dependent on a critical mass of users to make them useful [24]. Further, she observed that support for informal communication was needed due to frequent schedule updates and shifting that were not reflected in any shared artifact [23]. Other studies that have addressed the social uses of GCS's include work by Mosier and Tammaro [76], who found that while functional improvements to a GCS improved its acceptance by a workgroup, the culture of work within that group was just as important. For example, frequent meetings, interdependence, and periodic mobility defined a clear need for a group scheduling tool.

Most influential to the Ambush and Augur designs are the studies of calendar use performed by Palen and Grudin at Sun Microsystems and Microsoft [40, 83]. These studies were able to identify several facets of successful groupware calendar systems. Some aspects, such as a common infrastructure, managerial support, and peer pressure, focus on organizational properties of the institution. Another, usability, is an important property of the software itself. Other aspects, address work practices at the site, and divide design considerations into three interacting perspectives, shown in Figure 2-2.

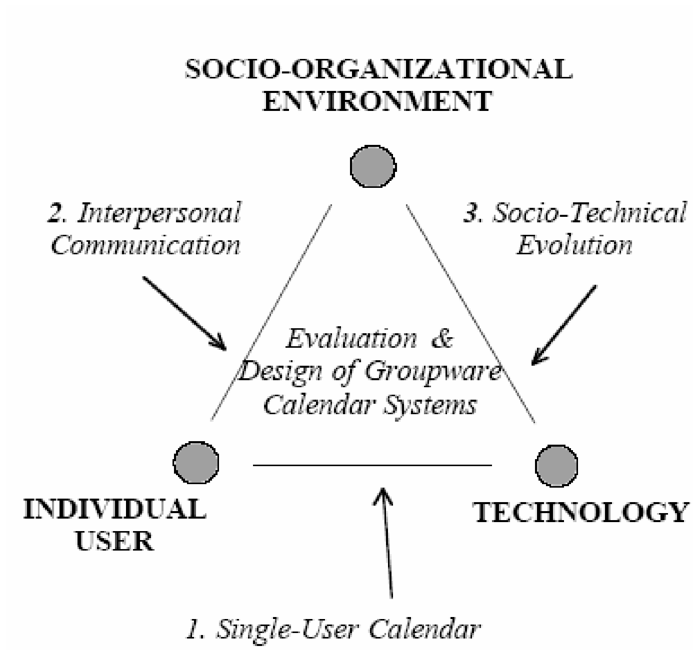

Figure 2-2: Perspectives on calendar use as defined by Palen [81]

1. Single-user calendars. For individuals, the calendar provides common functions such as reminding, orienting, tracking, recall, and scheduling. The location and format of the calendar, its form, are typically set for individual preferences with respect to their own calendaring habits – for instance if they are frequent or intermittent calendar users. Flexibility is necessary, both in the tools that users employ to edit their calendars and in the coding of calendar events. Payne's study of calendar use [85] provides insights on the variety of calendaring styles employed by office workers, including individuals' maintenance of multiple calendars.

2. Interpersonal communication. In addition to this perspective, calendars serve workgroups, most commonly through the practice of meeting scheduling. However, individuals also use the calendar to estimate the status of their colleagues in terms of availability, workload, and time allocation. Awareness of calendar sharing prompts individuals to manage their privacy through the calendar. Omitted or cryptic entries, access-control lists, and defensive scheduling are all employed to this end.

3. Socio-technical evolution. Lastly, groupware calendar systems evolve with their users. Often, initial defaults for basic calendar settings will shape group norms. For instance, the choice of an open or closed calendar sharing policy affects future attitudes towards sharing, induces a certain accustomed level of privacy, and helps to shape a calendaring policy commensurate with that expectation of privacy.

A key motivation for the design of Augur was the observation that flexible scheduling practices introduce inaccuracies or ambiguities that affect all three perspectives. For instance, colleagues' abilities to make estimates of availability from shared calendars are hindered by partial or overbooked schedules. Work practices can evolve to abandon or discount the calendar as a reliable artifact. An unpublished study at a large computer company found that calendars were often cluttered with recurring appointments that were no longer attended (Erin Bradner, personal communication). Mosier and Tammaro noted that on average 18% of those surveyed in their study reported scheduling problems due to out-of-date calendars [76]. Consequently, the calendar becomes an artifact that may not reflect one's true schedule. A two-month study of a seven-person workgroup within my academic department showed that only 52% of 381 calendar entries were actually attended. Conflicting appointments also contribute to inaccuracies. 12% of unattended appointments in the study were missed due to attendance at another concurrent event. "All-day" appointments such as holidays often prevent attendance at routine events, and were present on 60 of the 413 user-days in the study (14.5%).

In addition, typical groupware calendars give users little opportunity to indicate the importance or priority of scheduled events, often resorting to free/busy indicators that require additional interactions to set.

2.2.2.1. Improving the effectiveness of calendars

A number of research projects have aimed to improve the abilities of calendars to support their most basic functions, such as meeting scheduling, time estimation, and orientation. These systems have used both novel UI designs as well as varying degrees of machine intelligence, and are the forerunners of current research in forecasting presence and availability. I summarize some of the more influential work below.

Beard *et al* [3] describe a visual calendar intended to facilitate the scheduling of group meetings. Their implementation assigns each calendar entry a transparency level corresponding to the user-defined priority of the event, where lower-priority events are more transparent and the highest-priority events are opaque. Meeting scheduling then becomes a matter of overlaying user schedules and finding the least opaque area that could accommodate the meeting. In a similar vein, the work presented in the following chapter automatically assigns attendance likelihoods to calendar events. However, Beard *et al*'s calendar system provides a cautionary observation: users of their system were reluctant to make their opinions of event priorities public over concerns that the event's organizers would take offense or even punish them if the priorities were not sufficiently high.

The CAP system by Mitchell [74] used electronic calendar information as input to an agent that performed automatic meeting scheduling. While demonstrating that the details of calendar items could be used as input to an intelligent user interface, it made a number of useful observations about deploying such systems in an academic setting. It recognized the need for fast learning algorithms in cases where schedules are frequently overhauled. It also recognized that domains where perfect advice is required are not good candidates for a system where user preferences are dynamic and thus require a dynamic model. A similar calendar scheduling agent was developed by Kozierok and Maes [67].

Yan and Selker's Context-Aware Office Assistant [102], was designed to manage appointment scheduling at the office threshold. This system used a small interactive application inside the office to obtain the owner's willingness to meet with visitors.

Datelens [4] and Mackinlay *et al*.'s Calendar Visualizer [65] seek to improve the visual design of calendar displays to let users better identify patterns within their own calendars as well as relationships between multiple colleague calendars.

2.2.2.2. Intelligent calendars

A number of systems have been developed to incorporate calendar use information to teach an agent the scheduling habits of its users [60, 74]. It should be noted that while most of the aforementioned systems incorporate some form of learning to facilitate scheduling activities, they do not consider or attempt to predict the attendance of the user at the events scheduled. Therefore, these systems still treat calendars as the actual schedules their users will follow. The probabilistic calendar presented in this thesis is intended to support a broad range of uses, of which meeting scheduling is but one.

Both Coordinate and Begole *et al.*'s work rhythms visualizations incorporate electronic calendars as context. In addition, Coordinate allows non-scheduled but "sensed" events to be placed in a calendar, so periodic instances of idle time or absence can be inferred as regular events and shared with coworkers as appropriate. Begole *et al.* allow rhythms to be visualized against scheduled events, so periodic absence, tardiness, shifting, or early adjournment can be easily detected.

2.2.3. Presence and availability forecasting systems

As defined in Chapter 1, presence and availability forecasting systems integrate advances in machine intelligence with sensing technologies and existing groupware artifacts to accommodate the mobile and distributed nature of the workplace. Relevant work in this area provided research directions that led to the creation and study of the Ambush and Augur systems described in Chapter 4.

2.2.3.1. Inferring availability

The Adaptive Systems and Interaction group at Microsoft Research has been pursuing related ideas with work stemming out of their Attentional UI project [46]. Work on the Priorities system [45] introduced a context-aware model of attention intended to inform applications when a user was receptive to interruptions. By developing a Bayesian model of attentional states and weighing the cost of interruption against the cost of delaying the review of a potentially important piece of information, Priorities acts as a mediator for incoming notifications. While the goals of the applications proposed here are somewhat different, seeking to identify opportunities for informal communication rather than prioritizing and filtering such communications, the model developed for Priorities was a major influence on the model of event attendance presented later. Evaluation of Priorities has been ongoing internally at Microsoft.

A follow-up project to Priorities called Coordinate [48] has developed a query-based availability database intended to provide context to group awareness applications. Using a large database of collected data corresponding to user activity and location, Coordinate accepts queries, generates a Bayesian network from data most closely relevant to the query, and outputs a probabilistic answer to the query. Queries may include time-based questions such as "When is my boss returning from lunch?" or location-based questions such as "Where will my boss be at 3pm tomorrow"? This system takes a different approach from the Ambush/Augur systems presented later in that it builds its models from a large amount of existing data. Early experiments report a 92% accuracy in predicting meeting attendance for 100 events after training on 559 events.

BusyBody [47] builds on the concepts of the Notification Platform and Coordinate, providing a deployable, personally trainable infrastructure for determining availability and adjusting notifications accordingly. By clicking on a small popup window to indicate availability, users provide training data, achieving classification accuracies of 70% or greater after a few hundred examples.

Hudson *et al.* [50] used Wizard of Oz studies to build statistical models of availability using a variety of hypothetical sensors and model representations. This work found that a small number of simple sensors, including a keyboard monitor, phone monitor, clock, and audio level detector, could effectively predict availability. Decision trees were found to have a small advantage with respect to model performance. Later work by Fogarty *et al*. [27] incorporated the use of real sensors and established that such models, with sufficient training examples, were robust to field deployment among a variety of work environments and habits.

Fogarty *et al*. [28] have subsequently augmented an instant messaging client with predictions of interruptibility using statistical models and deployed it to several corporate workgroups in a month-long study. Through quantitative analysis of use logs, the researchers examined how predictive information affected their use of the client. They found that the client was most likely to be used when information about availability was needed in order to decide on initiating communication. Otherwise, conventional channels were used. Users tended to investigate additional details of availability, such as building presence and calendars, when the high-level status displayed by the client was ambiguous.

Kern *et al*. [58] have developed a wearable notification manager that incorporates information sensed both from the wearable user's activity and the activity within his environment. This builds on earlier work by Sawhney *et al*. [88] for managing notifications using personal and environmental context.

Recently, Begole *et al*. have developed Lilsys [5], an availability-sensing system that is integrated with Awarenex to provide a degree of control over inferred availability information. Using motion, audio, and keyboard input sensing as well as a decision tree model of availability, Lilsys presents the state of the sensors to the user and allows a timed override for indicating high unavailability. The intent is to provide some degree of control for exceptional periods of unavailability while inferring availability status most other times.

2.2.3.2. *Sensing presence*

Research using the Awarenex system has generated a great deal of location data for a small workgroup at Sun Microsystems [7]. Simple visualizations, along with correlations to user calendars, showed that the potential existed for building predictive models of user location. Recent work by Hill and Begole [44] has resulted in the development of user models for predicting location over the course of the day using these work rhythms.

Work by Ashbrook and Starner [2] uses hidden Markov models learned from GPS logs to predict future location at a fine-grained level to identify potential collocations of colleagues. This work shows much promise, but variance in time and location makes it difficult for colleagues to know just exactly when and where they may meet. Tempus Fugit [29] performs estimation of arrival times at events based on current attendee location. The predictive powers of the system are limited to near-term events and are not intended for longer-term planning over days or weeks.

Liao *et al*. [63] have used dynamic Bayesian models and particle filters to first determine the transportation mode being used, then to use that information in estimating future location. Smith *et al*. are using PlaceLab to estimate location using particle filter techniques applied to Wifi and GSM signal strength [89].

The systems described in the next chapter were designed in support of Palen's findings on GCS use. They differ from pure machine learning approaches such as Fogarty *et al*. and Horvitz *et al*. in that they rely on a manually-created model built from qualitative observations. Like MyVine, they contain novel interface designs intended to be incorporated into existing group communication tools.

Chapter 3: Evolution of a predictive calendar system

In this chapter, I will describe the design, development, and iteration of a predictive calendar system. Beginning with the motivations behind a single-user predictive calendar called Ambush, I will report on the design challenges and implementation issues associated with this proof-of-concept system. I will then describe the refinements to the system architecture, reasoning mechanisms, and user interface that led to a deployable shared calendar system called Augur.

3.1. Calendars as sensors

The groupware calendar serves dual roles as both a record of upcoming events as well as an indicator of presence and activity for both people and applications. While the GCS has long been a tool for group coordination, the more nascent field of ubiquitous computing has seen the calendar's role expand as a means of providing time-based activity information to applications. For example, incoming messages can be sorted by relevance based on the presence of related upcoming calendar events [68]. The activities associated with calendar events can be used as one factor in determining a user's attentional state [46].

In all of these cases, the personal calendar can be viewed not only as an information storage artifact, but as a sensor that can inform software applications as to the location, availability, and workload of a person. Like many sensors, the calendar is a portable object that can serve multiple components in any number of environments. In addition, the information contained within the calendar is dynamic, requiring periodic updates by programs using it. Perhaps the most important similarity, however, is the potential for inaccuracies or ambiguities in the information presented to applications. Systems that attempt to use calendar information to locate individuals or determine their availability ignore the actual attendance habits of calendar owners. For example, two events may have a time conflict, with an important isolated event overriding a routine recurring event. In another case, the user may lose interest in a recurring event and neglect to remove it from the calendar.

The calendar-as-sensor perspective is related to Palen's observations of colleagues who use the calendar to determine availability. For users who regard their desk time as "quiet time" for productive, heads-down work, ambushing and/or waylaying may be viewed as a reason to not participate in a GCS. The location information available through public calendars is invaluable to coworkers who are attempting to 'drop in' on a colleague, whether through office visits or encounters at some other event. In the academic department that served as the setting for my field studies, as well as in other research settings, a great deal of work is accomplished through this type of informal communication. While meetings and courses make it difficult to catch up with students and faculty, deviations from the schedule outlined on a public calendar exacerbate the problem. An accurate representation of the events to be attended improves a coworker's ability to infer this information. To this end, a new approach was developed to enable applications that provide a more accurate picture of coworker location and availability. As a proof of concept, I developed a predictive calendar application for a single user that shared predictions of attendance at future events with that user's colleagues. These predictions were offered to allow colleagues to make informed decisions about the best times to initiate informal communications.

3.2. Ambush: A simple predictive calendar

The task of predicting attended events on a user's calendar has an inherent degree of uncertainty. It is sensitive to situational details, conflicting priorities, and unforeseen events that are difficult to sense. However, by using past attendance history and extracting features from the attributes of calendar events, it is possible to present a likelihood of attendance to applications. Using a Bayesian network model of the priorities in event attendance as its core reasoning mechanism, Ambush generates predictions from this model and displays them to users in the context of a calendar application.

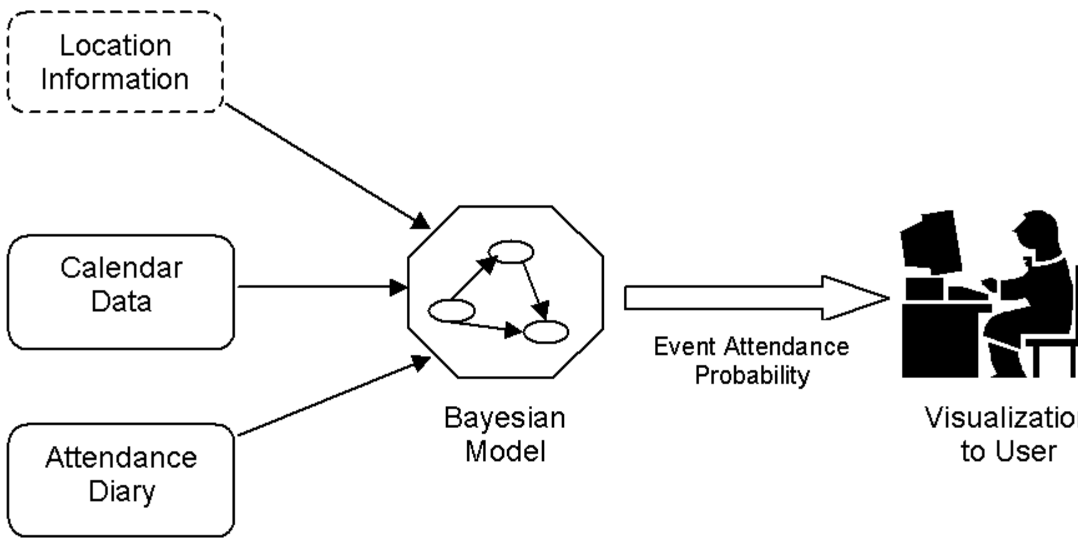

Figure 3-1: Ambush system diagram.

Figure 3-1 provides an overview of the system. An "attendance diary" kept by the calendar's owner lets the system use a form of supervised learning to improve its predictions over time. Autonomous components scan for new diary entries and use them as evidence to teach the model. Application programmers can then use the model as a sensor to make more informed assumptions about a person's schedule. Should infrastructure exist to allow location sensing for the user, such as an active badge or GPS location, the early models built for Ambush are structured to incorporate this additional information.

3.2.1. A model of attendance: a user-centered approach

3.2.1.1. Constructing the model

To model the intrinsic uncertainties in the attendance of users at their scheduled events, a Bayesian network was constructed for Ambush. Bayesian networks provide a compact, descriptive means of encoding uncertainty in systems where there is a fair amount of structure and a store of prior knowledge about the system in the form of either collected data or experts. In addition, the inherent structure of a Bayesian model and graphical representation lends itself to an explanatory interface component that illustrates the factors contributing to the model's predictions.

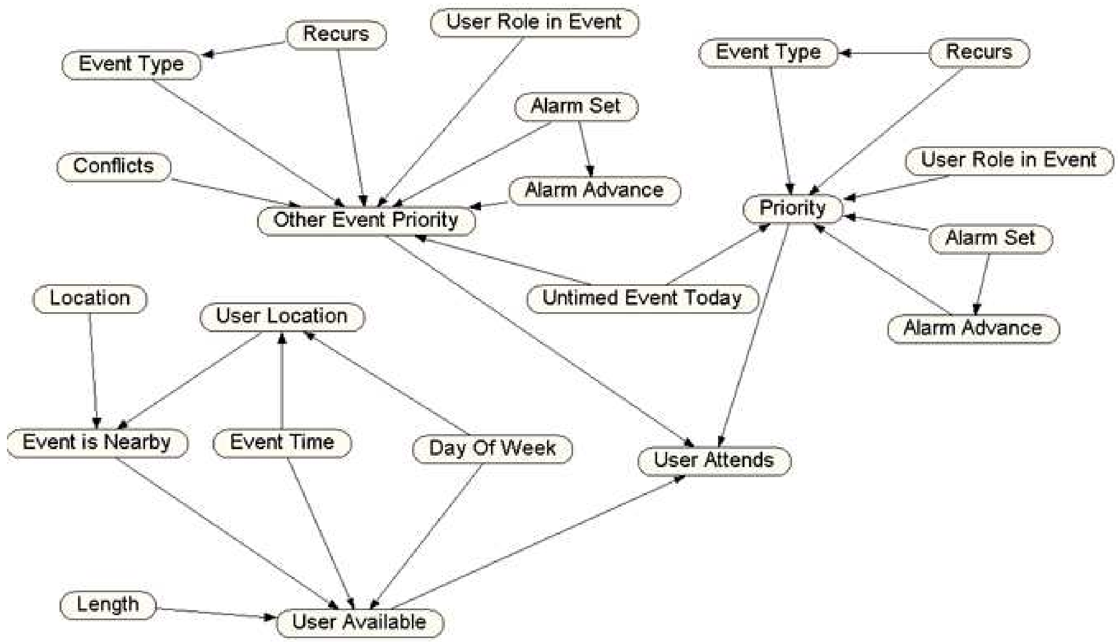

Figure 3-2: Bayesian network used by Augur to model event attendance.

Figure 3-2 illustrates the model used to determine the likelihood of a person's attendance at a given event. This model was created by hand using Norsys Corp.'s Netica belief network software. It specifies the decision to attend as a result of influences from the priority of the event, the priority of a conflicting event (if one exists), and the current availability of the potential attendee. To arrive at the network, students and faculty within an academic department were interviewed informally. This work resulted in a list of items considered by interviewees to have some influence in their decisions to attend an event. Using this list, I then worked to define the structure uniting these factors toward a single variable. The majority of factors listed seemed to contribute to an assessment of the event's priority and the person's physical proximity to the event. These were established as meta-criteria in the model, exerting direct influence on the final decision to attend. Other information garnered from interviews concerned the existence of conflicting events. Therefore, an additional branch of the model was added to handle the existence of such a conflicting event. To determine the variables that would be depicted as nodes in the network, common decision factors were identified that were mentioned by many of the interviewees. While it is not a comprehensive model of all factors that one considers when making the decision to attend, it captures the major influences that were identified.

To use the model in practice, those factors that could be sensed, either now or in the near future, were identified for the purpose of teaching the network through training cases. Sensing capabilities were limited by the choice of calendar format, and by the technology infrastructure of the research site. Although this step resulted in some paring down of the original network, factors that were determined to be the largest influences (e.g., the person's role in the event, his/her location, all-day events) were kept intact. The remainder of this section provides a more detailed description of the items comprising the network.

3.2.1.2. Model Description

The priority of an event is influenced by a number of factors obtained from its attributes:

- The alarm status (set or not) and the advance time before the alarm is to occur
- The recurrence status, whether it is daily, weekly, monthly, or yearly
- The type of event, whether it is a course, seminar, group meeting, individual meeting, office hours, or other.
- The user's role in the event, whether he/she is the organizer, a mandatory attendee, or a regular attendee.

- If the event is "all day", or untimed, it influences the priority of other events on the schedule, since such events typically supersede routine recurring events.

The model specifies proximity as the result of influences from the following attributes:

- The location of the event. In this implementation location is at the granularity of a building.
- The user's location, if available. In the absence of location tracking, the prior probabilities can be seeded to roughly correspond to the user's whereabouts.
- The event time, including time of day and day of the week, as well as the event's duration.

At the time Ambush was developed, students and faculty in the department shared their time between three different buildings that were not physically proximal to one another. While the infrastructure to provide fine-grained tracking of users across campus and beyond was not in place, there were capabilities for determining the building a person is currently in. This coarse location history, combined with prior information elicited through user interviews, allows the acquisition of probabilities that serve as a reasonable estimate for location. This aspect of the model was removed in future iterations when location sensing fell into disuse and a ubiquitous infrastructure no longer existed.

The existence of a conflicting event presents an interesting problem. In this case, the user can only be in one place at that time, so a judgment by the system must be made on which event is preferred. Therefore, the system considers the priorities of the current event and the conflicting event, as well as user availability, to determine an appropriate likelihood of attendance for the event. Priorities for both events are determined using the same criteria described earlier. A limitation of the model is that only one other conflicting event is considered.

3.2.1.3. User-centered modeling and machine learning

Since the development of Ambush and Augur, other approaches to modeling presence and uncertainty have been explored. Many of these projects were reviewed in Chapter 2, and research in this area continues to be active. The process used in modeling these attributes tend to either be user-focused, as is the case with Ambush and Augur, or a machine learning approach, as pursued by Horvitz *et al*. [48], Fogarty *et al*. [27] and others. While no method claims to be superior to the others, there are certainly advantages and disadvantages that deserve mention here.

Machine learning approaches identify critical features in the activity being modeled and learn from the patterns exhibited by a large collection of specific instances of these features. Learning can occur in advance if a large body of data (corpus) is available, or as a system is used. The advantage to this approach is that the model is formed from actual use patterns. Therefore it can be seen as an accurate representation to the extent that its training data is grounded in real behavior. This means that the training data must be a representative sample.

The difficulty with machine learning approaches, of course, is that they must have data available from which to train, and that upheavals in routine may necessitate the training of new models. In Chapter 6 I also discuss the tension between a completely accurate representation of activity and the impression management needs of users within a workgroup.

Ambush and Augur take a more user-centered approach, building models by hand using qualitative examination to determine prior probabilities. While this technique is used in a number of fields such as the construction of medical expert systems, and somewhat formal methods for model elicitation have been developed [96], it is still vulnerable to user biases. In addition, if the model is to be deployed to members of a group, as with Ambush and Augur, individual differences can cause the model to be more or less appropriate to the behaviors of each individual.

The attendance diary used by both Ambush and Augur allows for these systems to take a somewhat hybrid approach to user modeling in that hand-modeled networks are able to learn over time from a supervised learning algorithm. In Chapter 4 I examine the results of this approach.

3.2.2. System architecture

Ambush is implemented in three components. The first is the web-based attendance diary that presents the calendar's owner with a checklist of the day's scheduled events. The owner checks which events were attended and which were not, and submits the list. The diary is implemented as a CGI script, and calendar data is obtained by parsing the owner's Palm datebook file. Unlike many organizations, the academic department that constitutes Ambush's target environment does not have a standard groupware calendar system available to all students and faculty. As such, the most commonly used calendar system turns out to be the Palm datebook. Additionally, by using the PalmOS calendar, Ambush was able to better support existing personal calendaring practices rather than force users into an institutional infrastructure.

A second module, running in the background, checks for new submissions from the attendance diary, converts them into learning evidence for the Bayesian network, and saves a new network with updated probabilities that reflect the new evidence. Network learning is performed through the algorithms provided via the Netica API.

Many of the Palm datebook fields have straightforward mappings to the variables in Ambush's Bayesian model. Several variables, however, such as User Role and Location, do not have equivalent fields in the Palm datebook. Therefore, simple text parsing of the event title is performed in an attempt to extract evidence for these variables. For instance, if a particular course number is found, the location can be looked up using the school course directory. The calendar owner's status as faculty or student establishes his or her role in that course as either attendee or organizer. Other proper names and keywords are also used to provide similar mappings.

A third component, implemented as a C++ class, takes a given calendar event, sets its attributes as evidence to the Bayesian network, and performs probabilistic inference to arrive at a likelihood of attendance for the event. Again, the Netica API is used to perform network manipulation and inference. Other nodes of the network can be examined as well, and one can even determine the variables that are exerting the most influence on a given variable. This class is intended to be available to any application programmer who wishes to incorporate probabilistic calendar data.

It should be noted, however, that the Ambush system was also intended to act as a sensing mechanism that could provide applications with both calendar information for users as well as attendance probabilities. A simple wrapper class such as those provided by the Context Toolkit [19] would easily make such functionality available to context-aware systems.

3.2.3. User interface considerations

Several simple visualizations of the uncertainty expressed in the Bayesian model were created for Ambush in the hope of effectively conveying the likelihood of a person's attendance at a given event. Each visualization had a different purpose behind its design, and ultimately gave way to the color-coded design presented later in the discussion of Augur. I will briefly describe each visualization below.

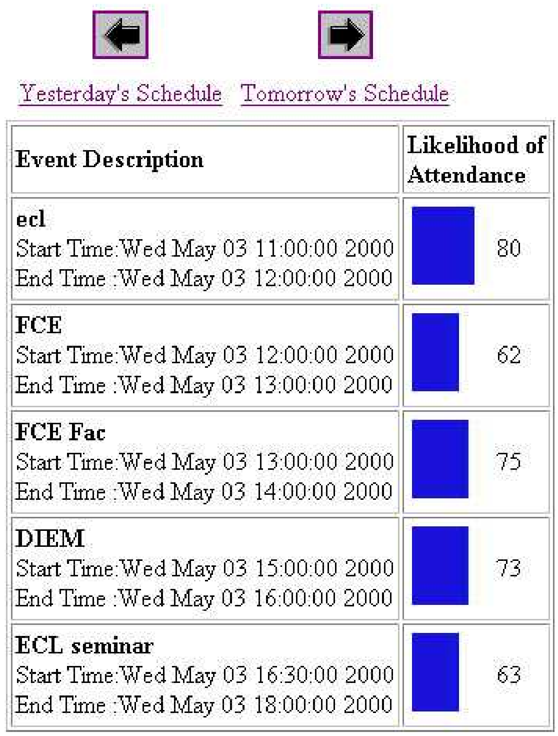

Figure 3-3: The Ambush user interface.

The first attempt at a graphical depiction of Ambush's output was to display a basic bar graph (Figure 3-3). While simple in design, the prototype clearly shows the relative probabilities of attendance for the day's events. The disadvantage is that fine-grained depictions of probability tend to be more than users actually need in terms of interpreting them. Future visualization attempts instead discretized the range of probabilities into a more meaningful set of values.

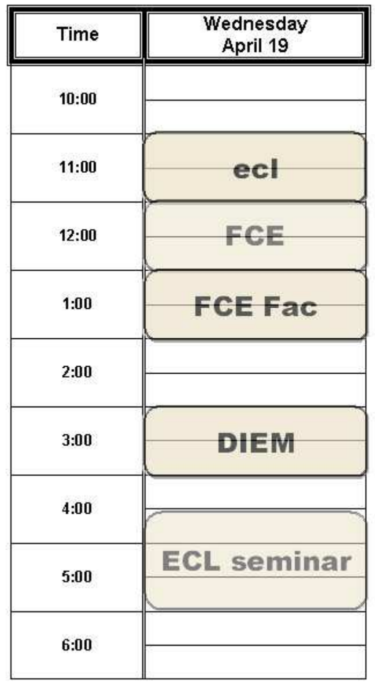

Figure 3-4: Prototype interface using transparency to represent attendance likelihood.

Another prototype used a transparency technique similar to that employed in the work of Beard *et al.* [3], instead mapping transparency to likelihood of attendance (Figure 3-4). While the mapping between transparency and probability is not apparent, it gives the impression that an event is more or less "on" the calendar.

In both of the prototypes just presented, the probability of attendance is represented as a single scalar value that may or may not be reasonable to the viewer. At times, the model must make uninformed predictions due to a short learning period or a novel situation. In these cases, the user should be able to access more information about the model for the purpose of diagnosing or verifying its predictions. Therefore, one visualization attempts to visualize the model's internal influences for users who may be skeptical of its output. The design is loosely based on feature maps [64] and visually captures the relationships and degrees of influence of variables within the model.

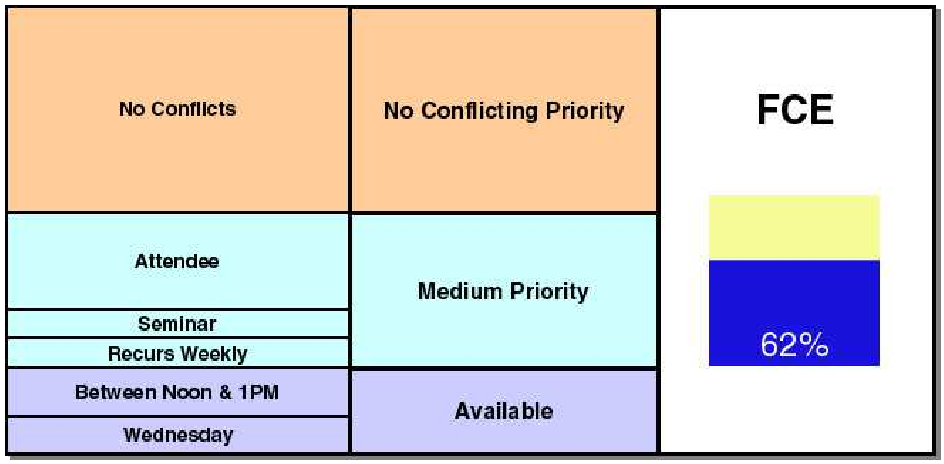

Figure 3-5: Feature map prototype indicating relative influences of variables on Ambush's attendance prediction. Related variables are grouped by color, and stronger influences are represented as larger boxes.

This visualization is shown in Figure 3-5. The boxes to the left of the bar graph comprise the feature map. Subdivisions within the map represent variables in the Bayesian model of Figure 3-2, and are organized to indicate

the most important influences in the network and their relationships, determined through a sensitivity analysis. Therefore, only the most influential variables are represented in the map. Larger boxes indicate greater influence on related variables. Variables that exert the most direct influence on the final prediction are further to the right.

3.3. <u>From Ambush to Augur</u>

In this section I describe how the lessons learned from the design of Ambush influenced the development and subsequent study of Augur. I outline the refinement of event attendance models, the iteration of the user interface, and architectural changes. Lastly, I describe how Augur was modified to allow for long-term study among a larger user population.

3.3.1. Lessons learned from Ambush

Ambush proved to be a useful proof-of-concept system in terms of establishing the feasibility of predictive calendars, the potential directions for future study, and areas for improvement.

While no formal analyses were conducted with respect to the accuracy of Ambush's models, observations of the output over time seemed to indicate that patterns of attendance at recurring events were improving as additional attendance diary entries were submitted. This encouraged the development of a new architecture better able to handle attendance models and calendars for a large number of users. More flexible means of identifying attributes such as event type and location needed to be devised as an alternative to manually maintaining a list of keywords.

In addition, presentations and demonstrations of Ambush elicited interesting reactions from people regarding the appropriateness of predicting and sharing attendance information. It was clear that future study of systems such as Ambush would have to address privacy preferences and the impressions that people try to maintain with respect to their coworkers.

To study such a system, logging functions would be needed to capture use, record predictions, and archive versions of user calendars and attendance models. For security purposes, some sort of encryption and login process was also a possibility, although the addition of authentication into the system introduces a barrier to use that can (and did) affect adoption rates. Although the attendance diary is a burden to the user, no sufficient location tracking infrastructure became available to automatically log attendance. In addition, the diary does introduce some small level of control over the reasoning of Ambush, so for the purposes of future study it was left in the system.

Lastly, although no formal evaluations were conducted on the visualization techniques designed for Ambush, informal assessments by students and faculty within the department raised a number of issues, prompting several refinements to the prototypes. Users were able to perform comparisons of entries visualized using the modified feature map, identifying the key differences that produced the final prediction. However, the exact relationship between the influences represented in the map and the final scalar output was not clear. Transparency proved useful for performing direct comparisons between the potential attendance of two events, but had to be discretized to a fairly low number of levels in order for users to distinguish between them. A redesign of the user interface was needed to provide distinguishable, discrete levels of likelihood that could be immediately recognized by users. The additional complexities introduced by attempting to explain the predictions would be deferred until users' mental models of the system were better understood.

3.4. Augur: Augmented shared personal calendars

While working on Ambush, it was also clear that a predictive calendar needed to be studied with respect to all three perspectives as outlined by Palen [81] While to this point, the groupware calendar has been stressed as a tool of collaboration, it is important that it also support individual calendaring practices, interpersonal communication and coordination, and the socio-technical evolution of the calendar artifact. These different perspectives on the calendar, while distinct, interact with one another and, according to Palen, are critical to the successful adoption of such systems.

To directly support these work practices, Ambush was redesigned to produce the Augur system. Augur is an open model GCS for workgroups that considers the multiple use perspectives critical to successful deployment.

Single-user calendars: Calendar owners, especially those using mobile PDAs that emphasize individual use in contrast to coordinated corporate systems, are likely to have their own unique ways of representing events. Augur anticipates and compensates for this combination of inaccurate entries and ad-hoc naming to support the interpersonal communication practices described next.

Interpersonal Communication: GCS's also mediate group-oriented tasks. A common use of shared calendar systems is to find open times for scheduling meetings. While Augur permits this use, it emphasizes estimating the availability of co-workers for informal chats, and in particular, finding opportunities for conversation at shared events. Again, support of "ambushing" is at the root of its design. Users who show their availability at shared events may welcome the opportunity to handle short interactions away from their desk without resorting to email and voicemail channels. Augur allows inaccurate calendars to remain useful tools for initiating informal communication by employing predictive models of user attendance in conjunction with intelligent text processing. By visualizing the output of these models, Augur provides an informed view of a user's schedule that enhances a coworker's ability to infer her attendance at upcoming events.

Additionally, Augur was designed to support the management of communication resources at one's disposal. More accurate estimates of availability inform a user's choice of an appropriate communication medium. If it is unlikely that a worker can ambush a colleague on a particular day, he will probably use another method, such as writing email or a scheduling a meeting. This emphasis on shared events also leads to support for other informal collaboration practices. For example, estimations of attendance at shared events help users assess the importance of a particular event, either in terms of general interest or in the attendance of specific individuals. Likewise, an awareness of the distribution of colleagues at events throughout the week aids in understanding the actions and priorities of that group.

Socio-technical Evolution: Users develop work practices around an initial system design even as new features are added. For example, privacy concerns may increase as a GCS user population expands. Augur’s added facilities for managing privacy help to overcome the inertia of a calendar that is open by default. Users remain aware of their level of privacy even as the system's social environment changes. Privacy management is an important practice that often employs a combination of strategies such as access settings and omitted appointments. However, users depend on an awareness of how their personal information is being used by others to determine how they employ these strategies.

3.4.1. Refining the intelligent components of Augur

3.4.1.1. Bayesian network

For the first version of Augur, the Bayesian network presented earlier in Figure 3-2 was left mostly untouched. Priors were refined from the original Ambush network, which was largely designed for a single user. User responses from both demonstrating and piloting Ambush were instrumental in establishing prior probabilities that reflected the attendance habits of users within the academic department.

Note that the variables indicating user location were left in the network despite a lack of any means for sensing this state. Originally, the prior probabilities roughly reflected the whereabouts of Ambush's lone calendar owner. However, when refining Augur for study, relying on these priors for a variety of users became unrealistic. Therefore, the structure of the network was pared down for the study discussed in Chapter 4.

The attendance diary feedback system that allows users to train the model was still in place. While a burden to users, it was the most feasible way of letting users control predictions to some degree without major changes in the environment's infrastructure. Balancing user privacy with the ability to reliably log attendance at events remains an open issue. An encouraging technique used by Horvitz *et al*. [48] uses a simple metric for detecting drops in workstation activity to identify when someone has left the office. Hill and Begole's identification of transitions [44] could also be used toward this purpose.

The Ambush system used simple lookup tables to identify attributes such as event location and event type, fields that are not present in the PalmOS calendar format. For Augur, a novel application of text-processing techniques from the area of intelligent systems was employed.

3.4.1.2. Support Vectors for Event Classification

The support vector machine (SVM) is a machine learning algorithm that has found great success in the domain of text classification [54]. In simplest terms, SVMs learn a hyperplane classifier that achieves maximal separation between the two classes (true or false). Unseen examples are then tested against this classifier. Although SVMs use a linear algorithm, the optimal hyperplane may not be of a linear form. Therefore, a nonlinear kernel function can be used to map data to a different space where the linear algorithm can be applied. Work in text categorization has influenced the development of tools to parse additional information from the text of calendar entries.

For text classification, each calendar entry is represented as a feature vector. Each unique word over all event descriptions corresponds to a feature in the vector. Its value is the number of occurrences of that word in the current event description, scaled by its inverse document frequency (IDF). The IDF of a word *w* is defined as:

$$IDF(w) = \log \frac{n}{DF(w)}$$

Where DF(*w*) is the number of event descriptions in which the word appears and *n* is the number of documents. Several SVM models were trained to classify calendar events by their location and type:

- *Event locations* have four possibilities: one of three campus buildings (CCB, CRB, or ResLab) or other.
- *Event types* include courses, seminars, individual meetings, group meetings, office hours, and other.

An experiment using 1000 labeled calendar events was conducted, where 700 events were used for training and 300 for testing. By training SVM models using polynomial kernels of degrees one, two, three, four, and five, binary classifiers were created for each possible event location and type. The binary classifiers for location achieved accuracies ranging from 85% for the CCB location to 98% for the Residential Laboratory. Those for event type had accuracies ranging from 89% for Other to 99% for Office Hours. When combined together, Augur was able to correctly classify event type 80% of the time, and location 82% of the time. Since a large percentage of these events were over 2 years old and in some cases related to former workplaces of the participants, it is possible that more accurate results could have been obtained by using only recent events. As will be discussed in Chapter 4, these accuracies decreased when the algorithm was exposed to a large number of calendar events from a variety of users.

3.4.1.3. Identifying co-scheduled events

A critical feature of Augur is the ability to show a user that colleagues are also planning to attend the events he has scheduled. To provide this information, Augur must identify co-scheduled events, which are events that multiple users have scheduled on their calendars. At the lowest level, the system must identify calendar entries across users' calendars that represent the same event, or *co-scheduled* events. However, individuals enter events into their calendars using personal and often idiosyncratic coding styles.

Thus, the same event is often represented in many different ways across a set of personal calendars, and it is difficult for a system to automatically determine if any two entries represent the same event. For instance, each week there is a GVU Brown Bag lecture on campus, and individuals using Augur enter this event on their calendars using one of many possible descriptions: 'GVU Brown Bag', 'GVU brownbag seminar', 'brown bag', and 'gvu bb.' Some users may even employ multiple ways of describing the same event for different occurrences.

Augur extends an existing text processing algorithm to identify calendar entries that represent coscheduled events. Augur's entry-matching module (the EMM) uses the term frequency - inverse document frequency (TF-IDF) text processing algorithm [87] as its basis. As in SVMs, documents are represented as normalized, weighted document vectors.

The EMM discovers co-scheduled events by matching textually similar and temporally collocated calendar entries across calendars in the system. The event-matching algorithm uses all entry descriptions stored in the system as the document collection for the TF-IDF algorithm. The module creates a list of keywords by parsing each event description and adding all the words in the description to the keyword list. The EMM then computes an IDF value for each keyword. A similarity threshold is created based on the average similarity between past temporally synchronized calendar entries; synchronized entries start and end at the same time. Augur uses the average similarity of past events as a baseline and sets the similarity threshold to 40% of this baseline. Finally, Augur determines synchronized entries whose similarity exceeds the threshold to represent a co-scheduled event.

The EMM correctly identified approximately 94% of all correct matches for 7 users over the course of a month; 491 entries were scheduled for the month, and the system matched 146 entries. There were 17 entries scheduled and 4 matches on average per day.. The module incorrectly labeled 4% of matching entries; the module's false positive rate was 14%, and its false negative rate was 6%. The EMM more accurately matches recurring events than one-time events. Note that the EMM cannot match entries representing a one-on-one meeting using the TF-IDF algorithm because the entries representing the meeting are quite different. Instead, it matches one-on-one meetings by finding two temporally synchronized entries that both include the name of the colleague who made the other entry. The EMM identified 100% of one-on-one meetings in the data set using this method.

The threshold of 40%, while useful in a small group consisting of one research laboratory, proved problematic when expanded to a larger number of users and calendars, as is explained in Chapter 4. Since the calendar data is taken from a single workgroup, the event-matching algorithm can take advantage of a shared language for describing work-related events and locations. This language becomes broader with more users from different locations and research areas.

3.4.2. Augur Architecture

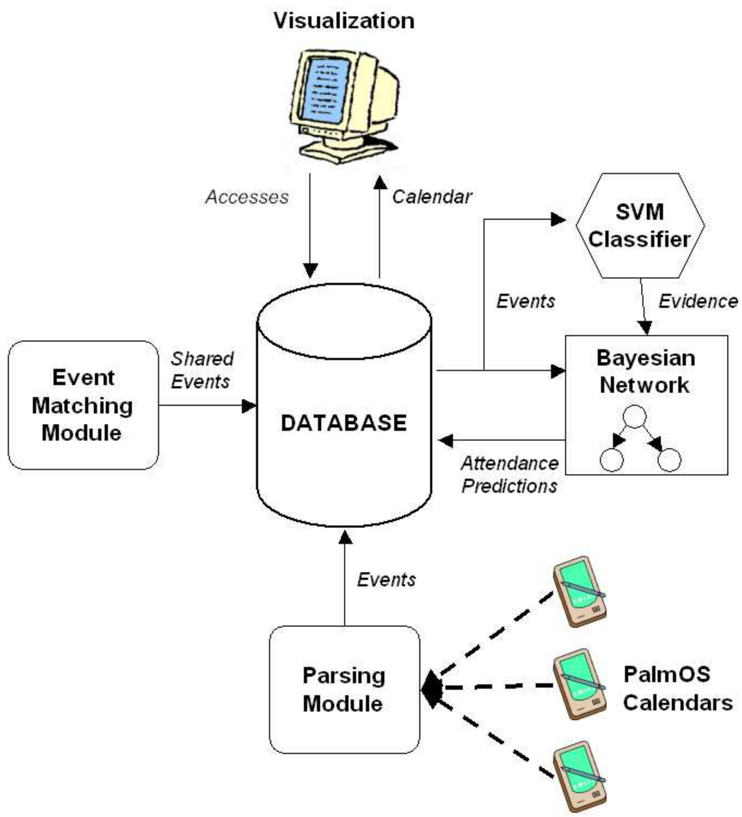

Figure 3-6: Augur system architecture

The Augur system is comprised of a number of components that process, store, and serve calendar information located in a central relational database (Figure 3-6). It retrieves user calendar data from PalmOS devices, augments the data with information about attendance likelihood and events coscheduled by colleagues, and serves that information to web-based visualizations that present the augmented calendar to each user and log calendar accesses. Thus, it offers similar functionality to Ambush, but supports a large number of users and provides personalized learning for each calendar owner on the system. In addition, Augur provides facilities for identifying event attributes and identifying coscheduled events.

To harvest calendar information, PalmOS conduit software was implemented to automatically send calendar information via FTP to the event parsing module upon synchronization with a networked computer. The parsing module reads the PalmOS calendar and updates a table of events in a SQL database whose fields are designed to match those of the VCalendar specification [97]. A user ID number is associated with each event to identify its owner. A second table lists the system's users and their IDs.

Once the latest calendar information is retrieved, Augur’s prediction and event matching modules insert additional information into the database. The prediction module uses the Bayesian network to add information about the likelihood of attendance for future events. Each user has a copy of the network that is capable of learning their attendance habits over time. An additional component allows users to provide examples to the system by submitting daily attendance checklists via the web. The event-matching module uses text-processing techniques to identify events from other colleagues' calendars that are likely to represent the same event. These modules are discussed in detail in the following sections.

With current, augmented calendar data now present in the database, web-based visualizations display this information to users. The owner's view displays his scheduled events along with information about whom he might see at those events. Information about accesses to those calendar events is also displayed. A second view, provided for the owner's colleagues, displays his events along with information about the likelihood of his attendance at those events. Additional software logs accesses to the visualizations and stores this information in the database.

All components are written in the Java language, while the visualizations use a combination of Java Server Pages (JSP) and dynamic HTML (DHTML). Database functionality is provided through MySQL. The Netica software was updated to a Java-based API for probabilistic modeling and inference, while the SVMLight support vector machine implementation classifies calendar events using their text.

3.4.3. Supporting interpersonal communication: The Augur UI

The original Ambush prototype offered a very simple UI that presented a bar graph and scalar probability of a person's likelihood of attendance at each event. Typically, users find it difficult to gauge the meaning of fine-grained, scalar values when probabilities are concerned [25], so alternative designs needed to be considered. While other visualizations were designed, they were either difficult to implement, as with the feature map solution, or presented usability concerns, such as the use of transparency. For the Augur UI, events were color-coded with their attendance likelihood along a discrete set of colors using a green-to-red stop light metaphor. In descending order of attendance likelihood, the color groups are: Bright green, green, yellow, red, and bright red.

In addition, the Ambush design required users to explicitly browse the calendars of those with whom communication was sought. Augur's ability to identify co-scheduled events meant that the system could more proactively display potential attendees at the scheduled events of someone browsing their own calendar. Thus, a nonintrusive, easily understood means of incorporating this information into a calendar display was needed.

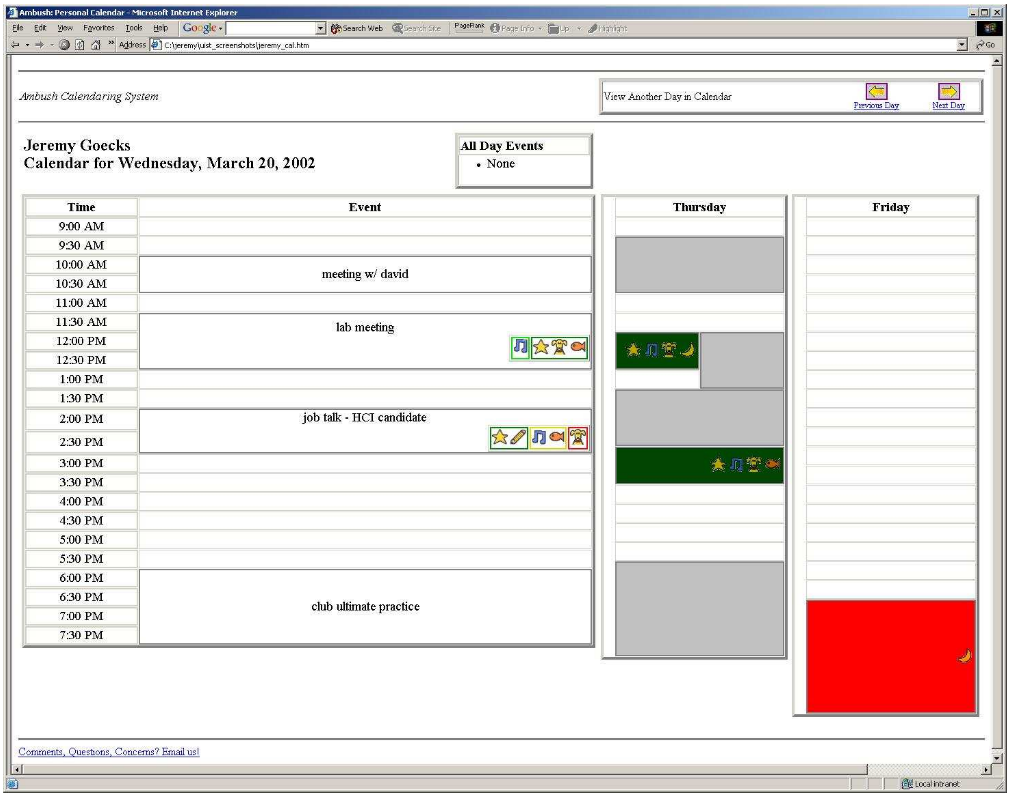

Figure 3-7: Augur user interface.

Most calendar systems are capable of displaying a tabular, hour-by-hour view of a user's scheduled events for a given day. Augur supplements this view with additional information to better support interpersonal communication practices. The augmented daily calendar is the primary Augur interface; Figure 3-7 shows a screenshot of the calendar.

The events on a worker's calendar are augmented with a list of icons that indicate which of the worker's colleagues have scheduled the same events. Each icon represents a particular colleague, and a colleague's icon is displayed within an event on the calendar if the colleague has co-scheduled that event. In the calendar shown in Figure 3-7, the user can see that four other colleagues have co-scheduled the 'lab meeting' event on their calendars. Icons are arranged horizontally left-to-right within an event according to the colleague's attendance likelihood for the event, letting a user compare the likelihoods among colleagues. In addition, an icon's opacity indicates the attendance likelihood of the colleague; the more opaque a colleague's icon is, the more likely the colleague is to attend the event. Lastly, colleagues are clustered based on their attendance likelihood using colored boxes; the color of the box around an icon group indicates the attendance likelihood of the colleagues in that box. These boxes let a user quickly determine how many colleagues are likely to attend or not attend an event.

To the right of the daily calendar are visualizations of the user's calendar for the upcoming two days, called 'bar calendars'. Their goal is to provide awareness of the user's upcoming schedule, including information present in the augmented calendar. As in a traditional daily calendar, the bar calendar represents events as blocks that span the event's scheduled duration. However, the bar calendar does not display the events' descriptions. Event blocks in the bar calendars are colored to indicate the overall popularity of an event; where popularity is sum of the attendance probabilities of all colleagues who have scheduled the event. Hence, events where the worker is likely to see many colleagues are colored green, events where the worker is likely to see a few colleagues are colored yellow, and events where the worker is unlikely to see any colleagues are colored red. Events scheduled only on the worker's calendar are colored light gray. As in the daily calendar, icons in the bar calendars indicate which colleagues also have scheduled events that are on the user's schedule.

Figure 3-8: Pop-up menu that appears over a colleague's icon in Augur.

The user can also interact with the calendar to obtain more information about colleague calendars. By mousing over an icon, a menu pops up (Figure 3-8). This menu identifies the colleague using his name and a small picture, indicates how likely the colleague is to attend the event, and provides a hyperlink to the colleague's calendar. When the user clicks on the hyperlink, an animation shrinks the user's calendar, hides the user's bar calendars, and displays the colleague's calendar to the right of the user's daily calendar(Figure 3-9).

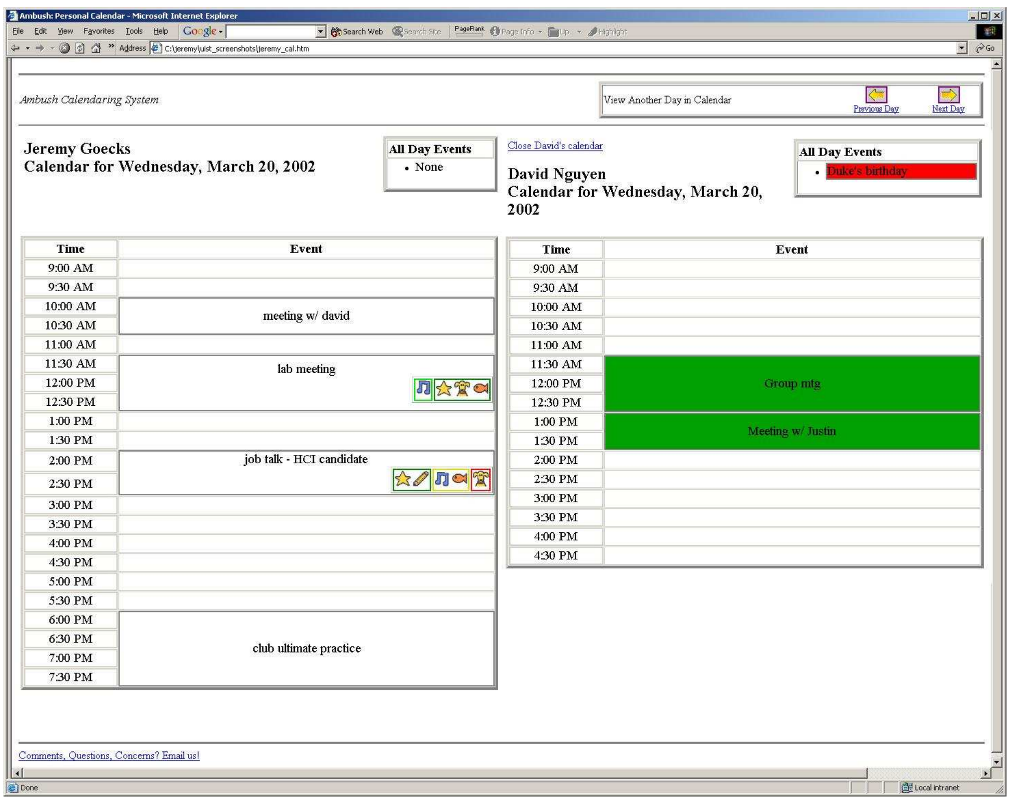

Figure 3-9: Augur user interface with two calendars shown side-by-side.

This allows the user to easily compare schedules and plan communication with the colleague accordingly. The event blocks on the colleague's calendar are colored to indicate the likelihood that the colleague will attend the events.

The augmented calendar supports the following interpersonal communication practices:

Ambushing: Each icon on the calendar indicates a time when both the worker and one of her colleagues may be in the same physical location; this time is an opportunity for her to ambush the colleague. She can also scan her daily calendar and the bar calendars to determine what events present many ambushing opportunities, or opportunities to be ambushed.

Resource management: The information on the augmented calendar helps users determine how best to communicate with their colleagues. If a user needs to speak with a colleague about a matter related to an upcoming deadline, he can view the calendar to determine if an opportunity exists to ambush the colleague before the deadline. If not, he can send email to the colleague or set up a formal meeting to discuss the matter.

Determining Meeting Importance: Grudin and Palen have observed that workers often determine a meeting's importance based on who is planning to attend the meeting [40]. The augmented calendar indicates who is likely and unlikely to attend an event, allowing a user to assess the event's importance and plan attendance accordingly.

Workgroup Awareness: A user can scan the augmented calendar and obtain a general awareness of her workgroup. A significant amount of green on a worker's calendar indicates that she and her colleagues are coordinated in their work.

3.4.3.1. Reflecting accesses to calendar owners

To support understanding of the socio-technical evolution of the calendar, an early version of Augur logged and visualized the accesses to calendars made by group members. This feedback was intended to provide awareness and accountability of not only the technical system but also the social system. A simple counter in the corner of each calendar entry displayed the number of times that event was viewed by another colleague. While this feature was not included in my long-term evaluation of Augur, it addresses an interesting potential need in groupware, namely the ability to have some type of translucence when personal information is accessed.

3.5. Preparing Augur for study

I piloted the Augur system for over two months in a workgroup that included five students, one research scientist, and one associate professor. During the course of this pilot period, I planned a larger-scale study of Augur to encompass more users from disparate research areas and buildings. The pilot deployment served to identify a number of design issues that required resolution before the study described in Chapter 4 could be conducted.

3.5.1. Architectural refinements

Augur was originally piloted with a single workgroup, but a planned study would expand the system to many more users, some potentially working from home. Since Augur had been running on a little-known internal laboratory web server with only a few calendars, the "security through obscurity" approach was sufficient to allay privacy concerns. However, a new, more reliable strategy was needed to accommodate a larger-scale deployment.

Though it presented an additional barrier to use that ultimately discouraged some participants, I decided to add an authentication process to Augur to allow access from outside the Institute and provide an additional layer of security for participants who were sharing personal events on their calendars to close friends or family members. In addition, I added access control lists to the user database to let participants share their calendars only with designated colleagues. This design decision also potentially limited the effectiveness of Augur by constraining the number of available calendars to any given participant, but most participants ultimately chose to share their calendars with any user of Augur.

To implement this added layer of security, the user interface generation components of Augur were transformed into a secure Java web service. An SSL layer was added for secure login, and all JSP pages were placed within an access-controlled directory available only to those who successfully completed the login process. To make the process easier, I added a "remember me" feature that would allow a user to login once and have their login information remembered by Augur for that user on a given IP address. Future visits to Augur would then take them directly to the welcome screen (see "UI refinements", below). The difficulty with this feature was that it required enabling cookies on the browser for the Augur website, and several users had trouble making this feature work.

In order to run reliably for several months, Augur required a level of integration that made its operation nearly autonomous. The initial implementation of Augur was a loose collection of programs that required a fair amount of manual execution. I wrote a unifying Java main class to integrate the classification of events, generation of predictions and co-scheduled events, and storage in the database. This process was run twice per day to keep the system current without bogging it down with Bayesian inference calculations. I ported the SVM component to Java using the libsvm package, with events classified as their calendar data was received by the parsing components.

In addition, it was clear that a single parsing component for PalmOS devices was insufficient for the variety of calendar applications used by students, faculty, and staff in the potential user population. I implemented an additional parser for the iCalendar specification, and some third-party conversion tools were used for applications such as Outlook and iCal. I discuss the existing calendar habits of the user population and the surveys conducted to elicit this information in Chapter 4.

3.5.2. Model refinements

As stated earlier, the Bayesian network originally developed for Ambush and Augur was not ideal for large-scale deployment for several reasons. First, the Ambush model was tuned to the needs of a single user, and would likely not apply to other users. Although refinements were made to prior probabilities for the development of Ambush, the structure of the model was overly detailed, containing variables such as "user location" that could not be sensed as evidence. Therefore, I again refined the Bayesian network for the evaluation of Augur.

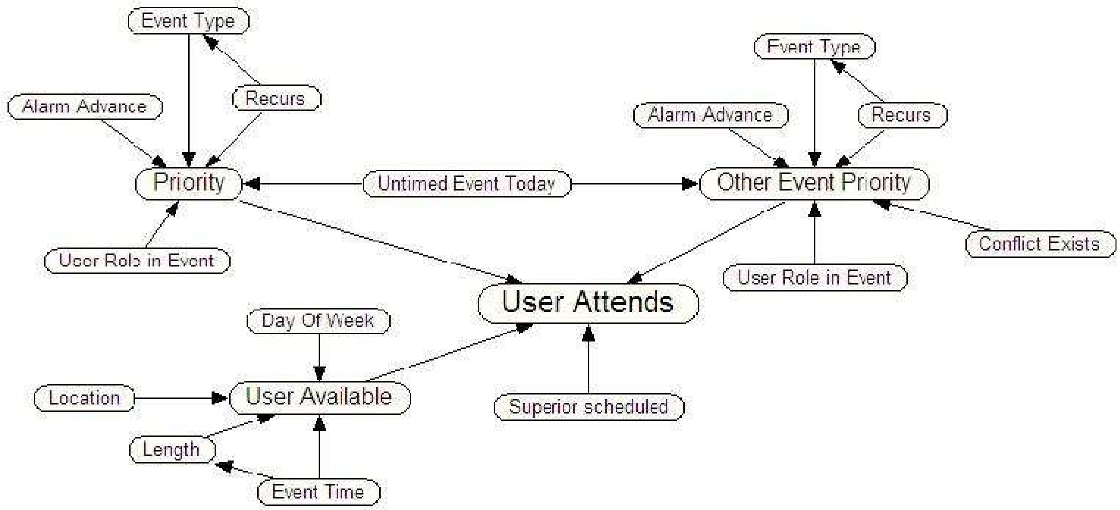

Figure 3-10: Modified Bayesian network used for the Augur field study.

The modified network is shown in Figure 3-10. User location was removed from the network. In addition, the notion of a superior having scheduled the same event was incorporated into the system. This addition was the result of feedback from both pilot subjects and the results from Horvitz *et al.*'s work on Coordinate [48], whose dynamically generated networks incorporated this attribute as a useful feature.

In addition, prior probabilities were revised once more to account for the new network structure and the feedback received while piloting Augur. User responses to initial surveys and interviews discussed in Chapter 4 were useful in seeding the appropriate likelihoods. While every Augur participant started with the same default Bayesian network, it could be customized by reporting attendance through the diary. While it would be infeasible to build by hand a custom model for each user, it may be possible to develop separate networks each job type (student, faculty, administrator, etc.), although in large organizations even this could quickly become too laborious. Chapter 4 will examine how the decision to use one model affected the accuracy of predictions.

3.5.2.1. *Tracking attendance automatically*

While for the purposes of the field study users still provided feedback to Augur through the use of a web-based attendance diary, as stated earlier, Augur's design was always intended to use a less-burdensome method of getting the same data. A lack of location-sensing infrastructure, however, made this infeasible.

Recently, researchers at Intel have developed a location-sensing system called Placelab [89]. By using information about the signal strengths of beacons with known, fixed locations in the user's environment, it is possible to calculate an approximate location for a user able to sense these beacons. In Placelab, beacons can take the form of GSM towers, Bluetooth access points, or WiFi hotspots. Using existing databases of GPS data for known beacons, users with wifi-enabled devices or GSM phones can build location-aware applications.

Using Placelab, I was able to build a component for Augur users that allows passive attendance tracking using WiFi signal strength from access points located throughout the campus-wide network at Georgia Tech as well as the greater Atlanta area. Location approximations are currently able to only give building-level accuracy, but machine learning approaches such as particle filter techniques may improve the precision. Consequently, the attendance-tracking component can only identify building changes and assume attendance at events where the rough location inferred from the event text (using SVMs) matches that returned by Placelab. In addition, it requires the user to have an active WiFi-enabled device on her person while attending (or not attending) events. A similar component could be implemented on Bluetooth-enabled or GSM phones. While not optimal, it is an important step towards making a system like Augur feasible for use beyond research purposes.

In Chapter 5 I will briefly examine how the addition of such a component can affect the privacy implications of Augur. In particular, I describe how the loss of control over a predictive feature can have repercussions on a user's ability to manage their availability and impression to others.

3.5.3. UI refinements

With an authentication step now added to Augur, the initial interaction with the system changed slightly. In the first version of Augur, users would navigate to a simple form that let them select a date and subsequently jump to the calendar for that day. Adding authentication, users were now presented with a username/password form that, if login was successful, would take them to a welcome screen that provided access to the user's calendar, attendance diary, and sharing preferences.

At the top of the welcome screen, the user is identified and their shared portrait (for indicating co-scheduled events on other users' calendars) is displayed. A link is provided that generates a popup window containing the names of all colleagues who have access to the user's calendar. Below this information, forms are provided to jump to a selected date for either the Augur calendar view or for the attendance diary.

Augur's first implementation used non-photorealistic cartoon icons to represent colleagues in the calendar because they provided a number of desirable qualities. The icons are simple, require little screen real estate, and do not demand the user's visual attention. It was believed that the mappings between colleagues and the icons that represent them would not be difficult to learn if the number of colleagues represented on a worker's calendar is small. However, users took time to adapt to these icons, and it was decided that using thumbnail photographic portraits of each user would be more readily recognizable. By letting participants choose their picture or opt out of using a picture altogether, the decision to use participant images did not present a privacy issue.

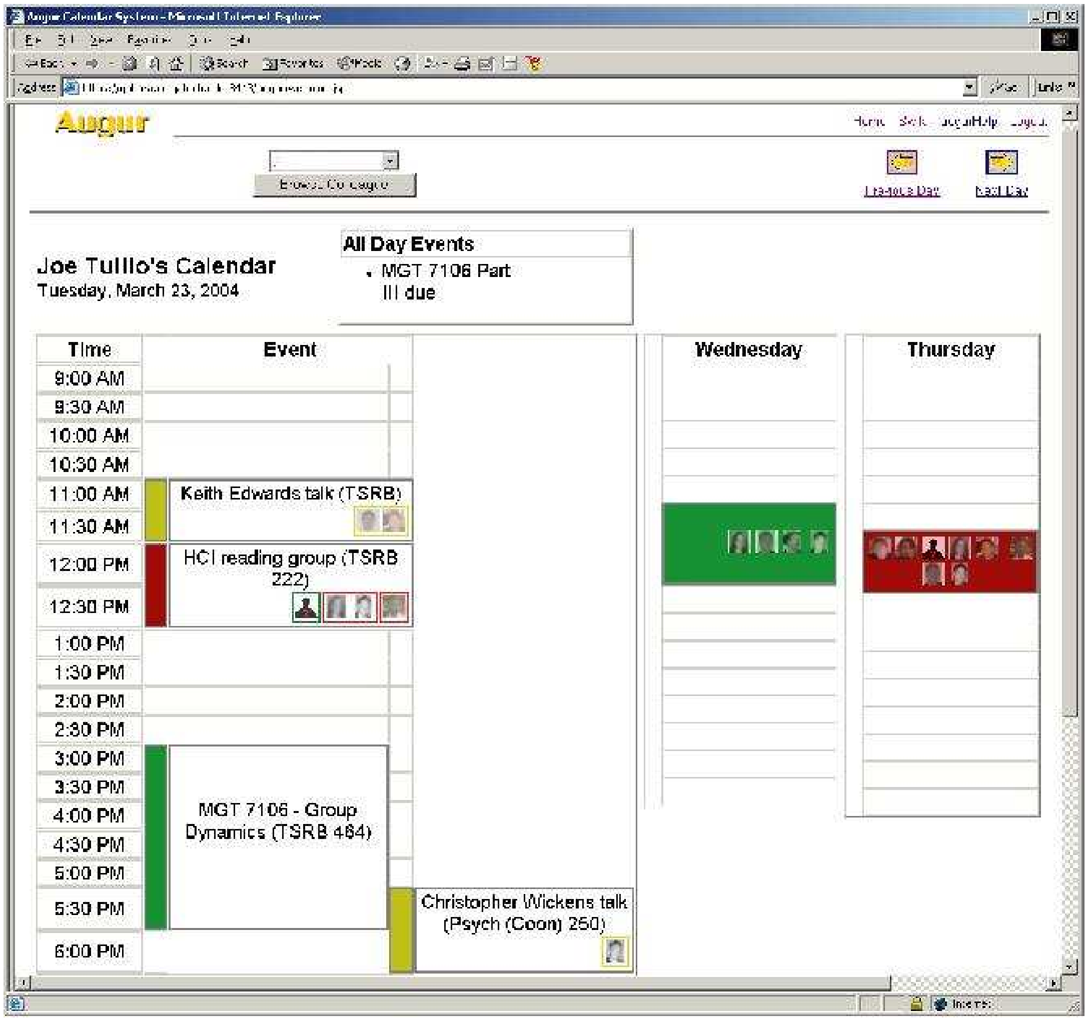

Figure 3-11: Augur user interface, updated for the field study.

In addition, the original UI design used two separate views for browsing one's own calendar as well as those of other colleagues. To simplify things, I modified Augur to use a single unified interface that defaulted to browsing the user's own calendar (Figure

3-11). Calendars of colleagues could then be viewed alongside it by either selecting the colleague's portrait from a co-scheduled event or by choosing the colleague's name from a list.

Lastly, color-coding of events to indicate attendance predictions was modified from the original implementation. First, while the predictions for colleague events were readily available, users had no knowledge of their own predictions for diagnostic or privacy-management purposes. Therefore, I modified the unified Augur calendar view so that predictions could be seen both for the user's events and for the events of any colleague he/she might be browsing.

In addition, coloring of events was limited to a small vertical bar to the left of each event on the calendar. Previous color-coding of the entire event cell had resulted in difficult-to-read text. By using a vertical color bar, the prediction was still readily associated with the event it described. In addition, the event text and the boxes around portraits of co-scheduled colleagues were clearly visible.

Once the necessary modifications were made to Augur, it became possible to conduct a long-term evaluation of the system with a larger number of participants. In the next chapter, I describe how the design decisions described here affected the adoption and use of Augur in the subsequent study.

Chapter 4: Evaluating Augur

Having described the design evolution of Augur, I now turn to the process by which Augur was evaluated and used within several loosely connected workgroups. This chapter presents the results of a four-month study of Augur in an academic setting. I present qualitative results demonstrating Augur's effects on scheduling and communication, privacy concerns, and adoption. These observations are supported with documented examples that illustrate how Augur affects the work habits of individuals with varying job descriptions, locations, and time commitments. In addition, I analyze how Augur supports colleague relationships, which can vary in degrees of copresence, meeting frequency, schedule awareness, and formality. I also examine the roles of impression management, domestic schedules, and exceptional events in the use of Augur.

4.1. Preparation: from pilots to a field study

Prior to the field study that is the focus of this chapter, I piloted the Ambush and Augur systems on small groups of users as a means of identifying bugs in the software and iterating on the details of the user interface. In addition, sub-systems such as the event matching module and the support-vector machine event classifier were tested for accuracy. The results of these tests, as well as the additional changes that were made to the user interface and system architecture, were reported in the previous chapter.

As explained in Chapter 1, however, Augur was not created as an exercise in machine learning solely to test the accuracy of its user models or as a proof-of-concept design. The ultimate goal of this line of research has been to examine the effectiveness of such a system in supporting informal communication practices, and to study the effects of sharing predicted information on social factors such as privacy and impression management. Therefore, I undertook the design of a field study that would examine these issues for a number of coworkers over a moderately lengthy (four month) period of time.

Few of the systems described in Chapter 2 have been subjected to a field evaluation, with researchers primarily focusing on system development and refinement of the core predictive models. One exception is the quantitative usage data reported by Fogarty *et al*. on the MyVine system [28].

To explore this domain more fully, I further develop a line of research that seeks to understand how forecasting groupware systems qualitatively affect the broader communicative practices of their users.

4.1.1. Choosing a site

Choosing the location of this study was a difficult task. The Ambush and Augur systems were designed using both observations from the work practices around my own academic department and the wealth of literature on electronic calendar use, primarily collected from industry studies. The site ultimately chosen was my own academic department. I will briefly outline the rationale below.

While most of the participants were considered collocated geographically, there is a high degree of local mobility due to events such as courses, seminars, and meetings. These events often take place in other buildings on other parts of campus and differ significantly between individuals. Therefore, whereabouts of coworkers are not easily deduced from simply being in the same lab, office, etc. In addition, a large number of coworkers in this department telecommute for some portion of the week due to family commitments or a need for seclusion to perform some important work. Certainly, anecdotal evidence suggested a need for a tool such as Augur prior to deployment. A sample email exchange prior to the study shows how local mobility can lead to a lengthy "hunt" when seeking out a colleague, and is indicative of an issue common to many students:

Date: Mon, 10 Nov 2003 11:42
Subject: Advisor Safari
Hello fellow grad students. If you spy my advisor this week, could you mail Jane? If you see him, don't make sudden movements or loud noises or he'll disappear again.
-Dave

Date: Mon, 10 Nov 2003 15:23
Subject: Re: Advisor Safari
Advisor was sighted not 5 minutes ago coming out of RSB [university building], repeat, advisor confirmed at RSB.
-Bob

Date: Mon, 10 Nov 2003 18:26
Subject: Re: Advisor Safari:
Fellow grad students:
The elusive advisor has been located. Thanks for your help. He has been tagged, inventoried, and released into the wild unharmed.
-Jane

Another difficulty with academic environments is the volatile nature of both schedules and personnel. Workers in academic environments are subject to term changes at least three times a year for the fall, spring, and summer semesters. Meetings and seminars that span term changes must often have their times and locations changed to accommodate the new course schedule, and personnel changes affect which people are scheduled to attend these events. These frequent upheavals make it difficult for machine learning algorithms that attempt to attain accurate representations of behaviors using an electronic calendar. Mitchell [74] has made the distinction between the task time constant, the time over which learned patterns remain stable, and the learning time constant, the time needed by an algorithm to achieve reliable learning. In order to reduce this learning time relative to system use, I designed the study to train models in advance prior to deploying predictive features. In addition, the study period did not cross any term boundaries, ensuring that participants' tasks would remain somewhat stable. As explained later in this chapter, it was difficult to obtain adequate training data within this time frame.

4.1.2. Academic environments and infrastructure

Perhaps the most challenging aspect of deploying groupware in an academic setting is the lack of a consistent group support infrastructure among participants. Studies of calendar use in industry benefit from the presence of a particular application such as Lotus Notes, Microsoft Outlook, etc. on the desktop of every employee, as well as written or unwritten policies that mandate the use of these tools for conducting work such as meeting scheduling. In contrast, groups within academic departments often run as autonomous laboratories that adopt their own methods for supporting coordination. Hardware and software use may even differ between individuals in the same workgroup depending on their level of interaction or collaboration.

4.1.2.1. Surveying calendar use

To address these concerns, I conducted an email survey of calendar use among members of the academic department. The survey, distributed to all graduate students, faculty, and staff, included questions about preferred calendar artifacts, sharing habits, viewing habits, and PDA use. The survey is included in Appendix A.

4.1.2.2. Results

A total of 103 people responded to the survey, including 70 graduate students, 28 faculty, 3 staff, and 2 deans. Each of the twelve sub-disciplines within Computer Science was represented, with HCI having the most respondents (27), and Intelligent systems and

Systems tied for the second most (15). The median number of responses for each area was 6.

As expected, the responses indicated that a number of different artifacts were used throughout the department for maintaining schedules. 70 of the respondents said they used some type of electronic calendar, 66 noted that they kept some events in their head, 42 emailed notes to themselves about events, 25 used post-its, and 26 used a paper calendar. Still others used spreadsheets, voicemail messages to themselves, notecards, and whiteboards. Of those that used electronic calendars, 29 used Palm desktop, 17 used Outlook, 13 used Yahoo! Calendar, and 7 used iCal, with others using Mozilla, Excel, and other applications. In terms of content, only half the respondents kept private events on their calendars. 89 kept professional events, and 67 kept personal events.

Surprisingly, 34 respondents were already used to sharing their calendar in some way despite lacking any institutional means of doing so[1]. The predominant means of sharing was via the web (15 responses), while other means included posting on doors or walls (10), using a server such as Notes or Exchange (7), Unix .plan files (6), hand-copying events to another calendar (6), or emailing (5). Nine respondents kept their calendars completely public, while most chose to share with some subset of close friends, family, superiors, or subordinates. Access control was maintained primarily through word-of-mouth awareness (14 respondents), but others used access control lists (9) or labeling of events as private (8). It should also be noted that several respondents indicated leaving certain events off the calendar that they didn't wish to make available to others.

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[1] It should be noted that the department makes a groupware application called Now Up To Date available to all faculty and staff, but not to students. Only one respondent reported using this application, sharing the calendar with one person, his administrative assistant.

54 respondents indicated that they viewed the schedules of coworkers. Of these, 25 used the unix finger tool, 24 used personal web pages, 16 looked at postings on the owner's door, and 9 accessed the calendar through some sort of server.

Lastly, PDA use was queried. 52 respondents had some type of PDA, with 43 owning a PalmOS-based PDA and 8 owning a PocketPC. Eleven respondents synchronized their PDAs daily, 12 synchronized every few days, 5 synchronized weekly, 13 synchronized approximately monthly, and 8 never synchronized.

Given these results, I decided that calendar use was prevalent enough to pursue a deployment within the department. Since almost 70% of respondents used some sort of electronic calendar, roughly 30% were already sharing in some form, and about 40% were using PalmOS PDAs, the proportion of eligible users was sizable relative to the department population. I determined that the academic setting would provide a challenging but potentially rich environment in which to study Augur's use. Participants would be able to synchronize a diverse range of calendar artifacts with the system while retaining their existing methods if needed. The significant schedule and personnel turnover that typically occurs during across term boundaries means that schedule knowledge internalized one term may be inaccurate the next. A number of different interactions, such as student/advisor relationships, faculty/staff relationships, and peer/peer relationships, could be examined to see which benefit the most from predictive calendaring. Lastly, the existing culture of sharing among many calendar users in the department meant that there was a potential benefit to such a system, and that their comfort with sharing additional, machine-generated information could then be evaluated.

A second email survey was conducted to determine the preferred browsers of potential users. The majority of users preferred Microsoft's Internet Explorer, while slightly less were using Mozilla's browser. A smaller number used Apple's Safari browser or Opera. This survey was used to ensure that Augur would work properly on the most popular browsers in the department.

4.2. Method

I designed the study to follow the use of Augur over a time period long enough to detect emergent practices that developed around the system. I sought participants from several workgroups comprising a range of different working relationships.

4.2.1. Participants and Recruitment

In recruiting participants for the study, I sought to obtain as diverse a population as possible in terms of occupations, closeness of working relationships, location, and use of scheduling technology. This population allowed for an exploratory study that could identify the strengths and weaknesses of predictive calendaring for a variety of participants and working relationships.

An email call for participants was sent to faculty, graduate students, and staff in a university engineering department. Participants were offered five dollars per week up to a total of $50 for participating. Participants were asked to self-report their event attendance, to be willing to have their use of the system logged, and in some cases to participate in interviews several times throughout the study period. They were not required to use the system as a tool for their work.

Twenty-seven participants were recruited to share their calendar data, with occupations roughly in the same proportions as the departmental population, with 18 students, 8 faculty, and one administrative staff member publishing their calendars. Also, roughly 30 others volunteered to have “read-only” accounts that permitted them to browse others’ calendars without contributing their own, with some of these accounts used by groups of people. In addition, the participant relationships ranged from people who were physically or occupationally isolated from other participants to students and advisors in the same labs who worked closely together.

4.2.2. Study structure

The study period lasted approximately four months, beginning in mid-January 2004 and ending in early May. Two participants, due to inaccessibility and technical hurdles, began the study one month late. Participants who were selected to participate in interviews were involved for the entire study.

I structured the study to first deploy a “plain” version of Augur that did not include predictions about attendance and co-scheduled events. After approximately six weeks, the predictive features were enabled, and participants used this full version of Augur for the remainder of the study period. The intent of this structure was threefold. First, the initial six weeks of the study allowed participants to adjust to a common calendar infrastructure. Second, it allowed comparisons to be made on use of the system before and after the introduction of predictive features. Third, the attendance information collected early in the study allowed models to be trained prior to exposing the predictive features to participants.

I used a combination of both qualitative and quantitative data collection during the course of the study. Prior to deployment, a number of logging routines were added to Augur. These routines captured logins and event views, and also archived predictions and old calendar information. Logs were not made available to study participants.

I collected attendance data by having participants complete a web-based form. This form displayed all of a participant's events for a particular day and reported whether each event was attended, missed to attend another event, or simply not attended.

I selected 13 of the participants (9 students, 3 faculty, one staff member) to take part in four 40-minute interviews each over the course of the study. They were selected based on the diversity of relationships they had with other participants as well as the diversity of their existing scheduling habits. They were first interviewed prior to Augur's deployment to examine initial concerns about privacy, expectations for the system, and existing coordination practices (Appendix B.1). A second interview was conducted after the "plain" version of Augur was deployed to gauge how this more traditional shared calendar was being used. Third and fourth interviews took place after the introduction of predictive features in Augur to elicit initial reactions to the new features and to identify the practices established around these features, respectively. The last three interviews used the same questions, included in Appendix B.2. These interviews provided the data for the results reported in this paper.

4.2.3. Relationships and Current Practices

To examine the use of Augur with respect to colleague relationships, interviewed participants were asked to select up to three colleagues with calendars on the system and to describe the nature of their working relationships.

In collecting this data, I hoped to arrive at a means of classifying participant relationships. Using these classifications, I could then examine how each type of relationship used the various features of Augur. I decided to classify along a few key dimensions of working relationships, using direct questions during interviews rather than resorting to post-hoc coding. I list these dimensions below:

Copresence - Each participant was asked how much time they were present in the same physical area as a particular colleague as a percentage of their work week.

Formality – Each participant was asked how often they met with a particular colleague, and how many of these meetings were either scheduled standing meetings or informal, unplanned meetings. They were also asked how often other tools such as email and instant messaging were used to conduct work in these relationships.

Meeting frequency – I distinguished between colleagues that met frequently versus those who interacted only sporadically. This also gave some indication as to the interdependence of the work of two colleagues.

Schedule awareness – Each participant was asked how much he/she knew of a particular colleague's schedule. This awareness could range from very little to a more detailed but self-centered perspective to a detailed knowledge that involved events unrelated to the relationship. Naturally, higher awareness of schedules corresponded to higher levels of copresence, keeping with the habituated patterns described by Weick [99].

Sufficiency of schedule knowledge – Participants rated how sufficient their knowledge of a particular colleague's schedule was for coordinating both planned and unplanned meetings on a five-point Likert scale.

4.3. <u>Results</u>

4.3.1. Quantitative results

4.3.1.1. Support-vector classifier

The support-vector machines for classifying events, determining their locations, and determining the roles of their owners were retrained for the study. As expected, accuracies dipped significantly when a much larger variety of event descriptions was presented to the algorithm. After training on 956 labeled examples, the resulting support vectors were tested on 408 separate examples. Accuracy for determining user roles dropped to 77.5% (MSE = 0.902). For determining location, the algorithm had an accuracy of 78.7% (MSE = 0.429), and for event type the accuracy was 70.8% (MSE = 1.89).

This drop in performance can be attributed to the fact that scheduled events no longer shared a common language in the way that the events in the pilot deployment did. While the labs that were involved in the field study were all under the same department, each has its own unique events in addition to department-wide courses and seminars. Moreover, the increased overall number of participants meant a larger number of events that shared acronyms or first names but were unrelated to one another (e.g., “bb” came to mean either “brown bag seminar” or “basketball” depending on the calendar’s owner). Given these results, it seems that it may be more effective to apply these algorithms individually, but this may be intractable for large numbers of people. A compromise may be to follow the example of the pilot study and train classifiers on localized workgroups.

4.3.1.2. Bayesian network model

Using logs of attendance predictions made by Augur and attendance logs submitted by a total of 20 participants, I determined the accuracy of Augur's attendance predictions. These results were calculated using two methods. In the first, I categorized each attendance prediction according to Augur's categories of very unlikely, unlikely, maybe, likely, and very likely. I then compared to whether the event was recorded as being attended or not. A prediction of unlikely or very unlikely for an unattended event, or a prediction of likely or very likely for an attended event was recorded as a correct prediction. Using this method, Augur generated correct predictions 57% of the time and incorrect predictions 11% of the time, with the remaining predictions (32%) categorized as "maybe".

To obtain a more concrete idea of Augur's predictive accuracy, I eliminated the "maybe" category and used a strict likely/unlikely (above or below 50%) criteria. Using this method, Augur was correct 66% of the time and incorrect 34% of the time. Interestingly, Augur's incorrect predictions were overwhelmingly optimistic; 88% of incorrect predictions were events predicted to be attended when they were not.

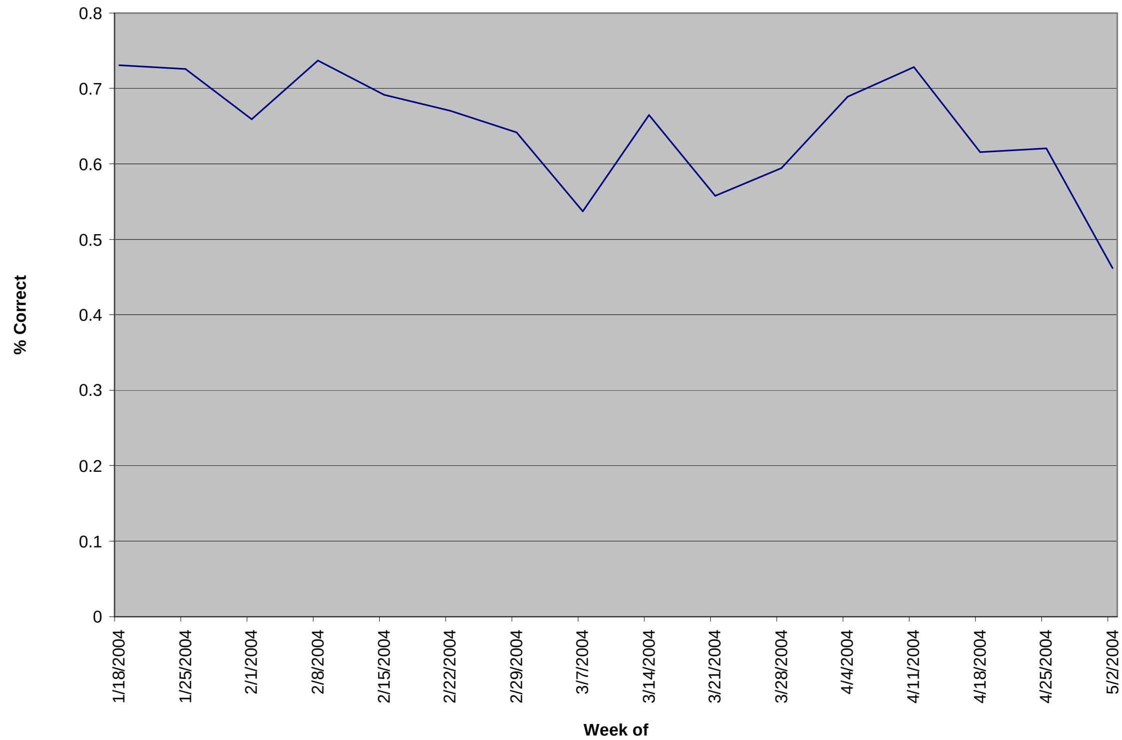


Figure 4-1: Augur's attendance prediction accuracy over time for 2337 events from 20 participants. Note the two troughs in the middle of the graph, which correspond to spring break and a convocation event.

A graph of Augur's accuracy over time (Figure 4-1) illustrates some of the inherent challenges in predicting attendance and learning over time. Two significant dips in accuracy can be seen the weeks beginning March 7 and March 21. These weeks correspond to spring break and a special convocation event that required many of the participants to organize technology demonstrations and lab tours. In addition, accuracy drops off substantially during the final week of the semester when classes are ending before final exams. A problem with these unusual periods of time is that Augur trained on the attendance data associated with them. Given that these times are not indicative of routine attendance patterns and that the Augur model has no means to encode them, they serve to introduce more error into the model.

In addition, the reduced accuracy of the support-vector classifiers only compounded the difficulties in accurately predicting attendance. Given that the attendance model uses classifications of location, event type, and role as input, errors in these variables will only add to the overall error rate of the model.

There were several relevant pieces of information that were not captured in the model. For instance, lack of a location sensing infrastructure was not present, so inferences based on travel distance relative to the time before an event could not be made. Perhaps more importantly, notions of interest were not captured in terms of the event contents and the research areas of individual participants. For example, a researcher in graphics would be more likely to attend a seminar on some graphics innovation. In these cases, more parsing and interpretation of content would be needed. However, the sparse, impoverished nature of calendars would not lend itself to this type of analysis.

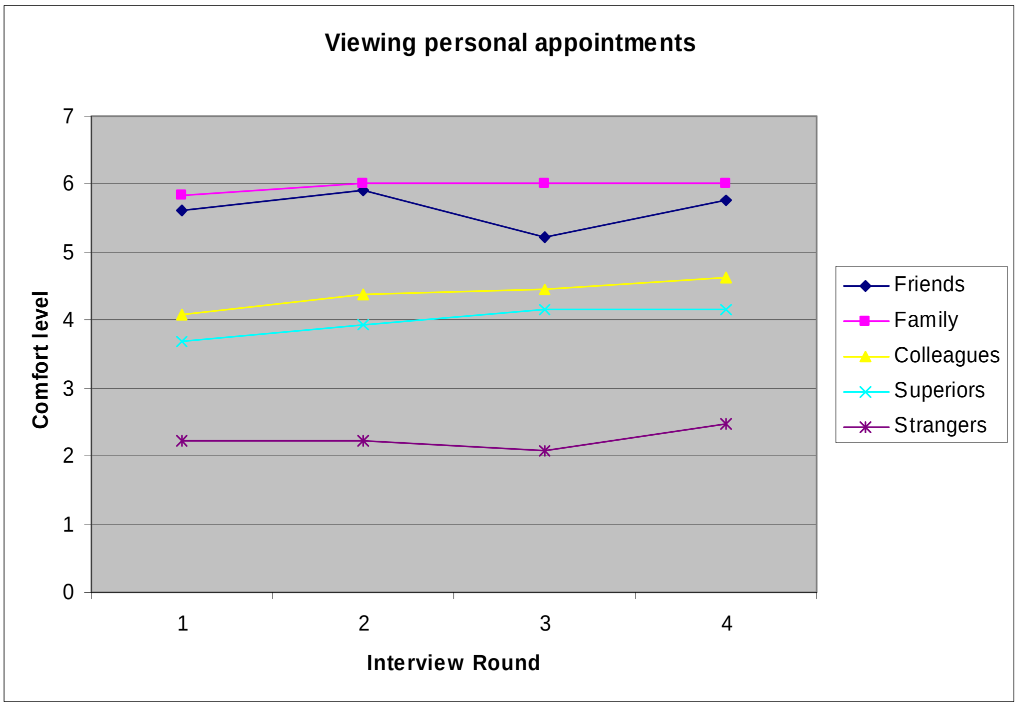
A solution to some of the above problems may lie in the use of institutional calendars that provide times of non-routine activity (e.g., spring break) and contain additional details about upcoming seminars and catalogs for academic courses. The use of such a calendar would allow for a more sophisticated model of the events occurring in the academic environment and perhaps improve its predictive ability.

Lastly, the number of training cases was at most 387 for a particular person, with a mean of 131.3, range of 364, and a median of 119. It is possible that many participants simply did not have enough training data to provide adequate learning during periods of relative stability.

4.3.1.3. *Privacy over time*

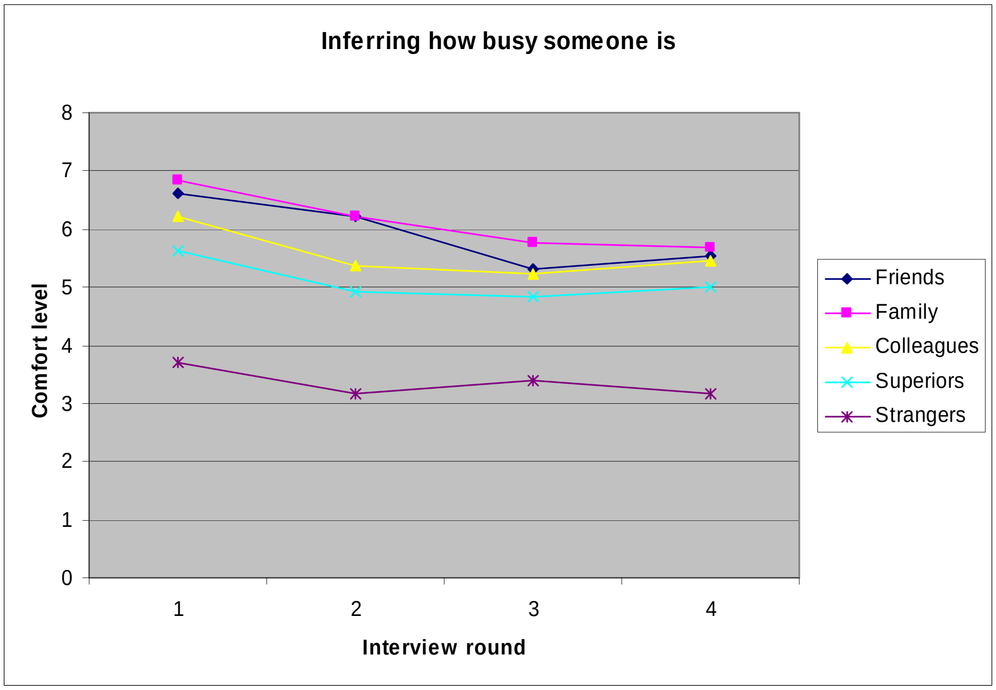
Participants were asked to rate their comfort on a 7-point Likert scale with friends, family, colleagues, superiors, and strangers using their calendars for various activities.

The following graphs show results over the four interviews during the study period. Interviews occurred 1) before deployment, 2) after the "plain" version of Augur was deployed, 3) after predictive features were enabled, and 4) at the conclusion of the study:

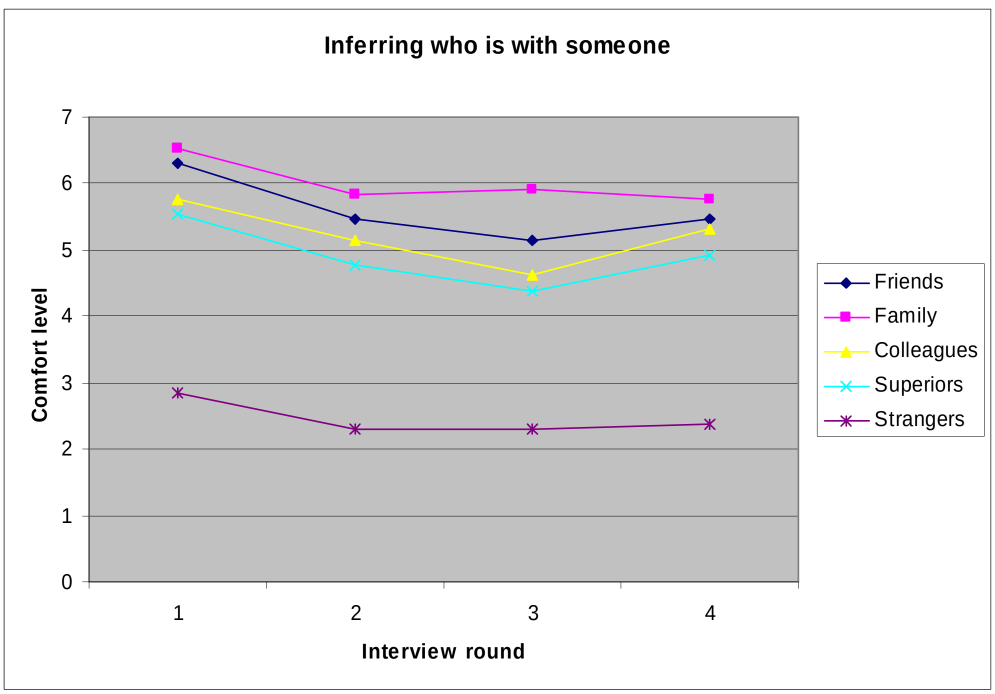


(a)

Figure 4-2: Participant comfort levels by interview round, where 7 is most comfortable and 1 is least comfortable. Participants were asked how they felt about different types of people (a) viewing their personal appointments, (b) inferring how busy they were, (c) inferring who they were with, (d) inferring their location, and (e) inferring what they were working on from their online calendars.

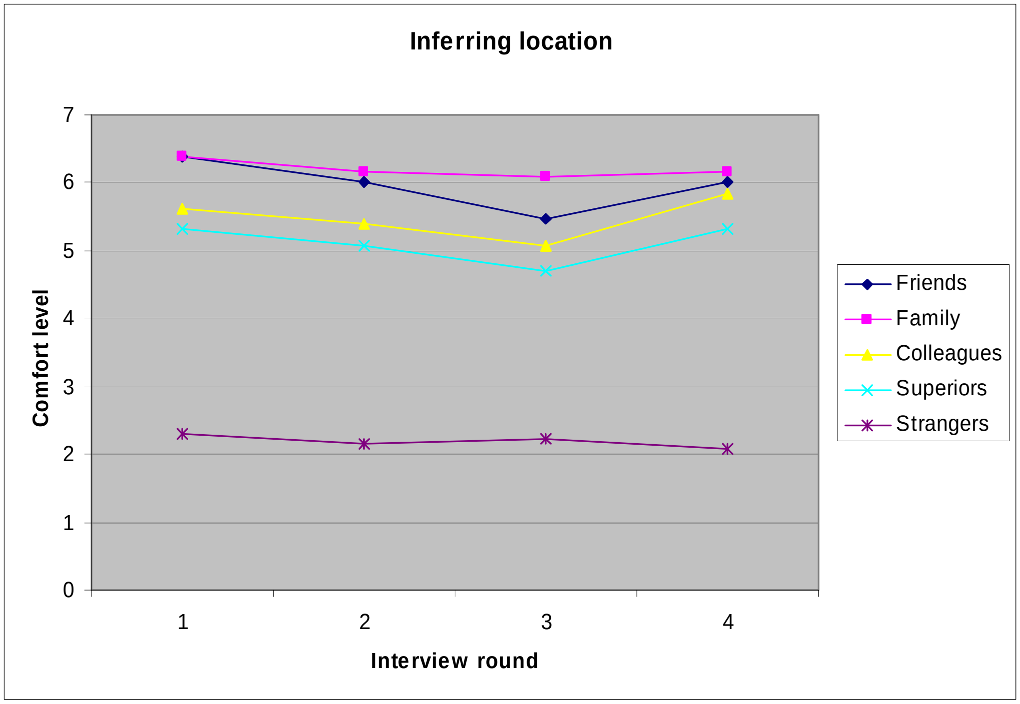


(b)

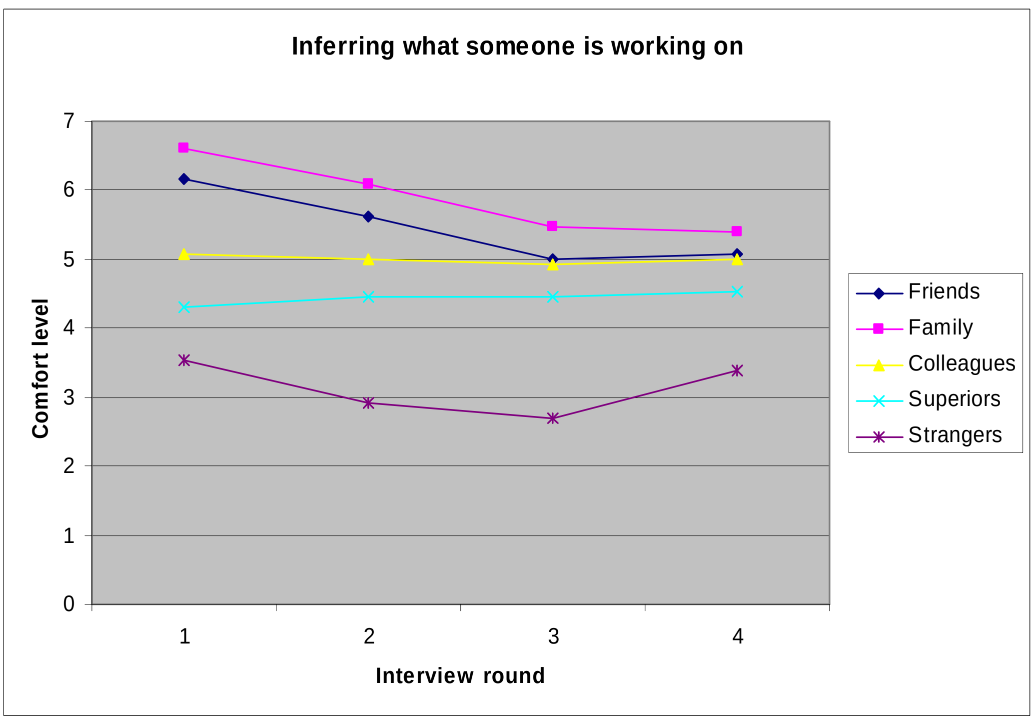


(c)

Figure 4-2 continued



(d)



(e)

Figure 4-2 continued

As seen in the graphs in Figure 4-2, trust in family was fairly stable across all potential activities over time. Conversely, trust in strangers was reliably low across all activities over time. Performing a within-subjects ANOVA on the data for friends, colleagues, and superiors, I determined that there was a significant main effect of round ($p < 0.05$) on both inferring what someone is working on, who he/she is with, and how busy he/she is. In addition, there were significant quadratic effects for responses for the latter two questions. Inferring location ($p = 0.33$) and viewing personal appointments ($p=0.763$) were not significant.

What these results would imply is that for certain activities, comfort levels started high, then dropped with the initial deployment of Augur. By the end of the study period, however, comfort levels had recovered somewhat. Reasons for this pattern are difficult to determine. The end of the study period coincided with the end of the semester, a time when schedules are notoriously unreliable. Perhaps people were more comfortable with these activities because their schedules were less accurate. Another possibility is that participants were generally more comfortable with being sought out, since somewhat more time is available once classes have ended. A larger, more focused study concentrating on these activities may help to explain these results in the future.

4.3.2. Qualitative results

Recall that Augur was designed to better support the groupware calendar's role in the canonical CSCW framework. While Augur users reported performing tasks such as manipulating calendars, communicating directly, and communicating through the calendar, more specific circumstances emerged as to when Augur was employed, and for whom. In addition, behaviors not directly related to work-related communication were observed that were nevertheless important to each participant’s role in the overall work environment.

4.4. System Use

In general, participants continued to rely primarily on their existing scheduling tools, the most popular being email and office visits. For those working fairly closely, tools were typically already in place to coordinate communication. In these cases, Augur was employed when these existing tools were deficient in some way. Overall, many participants employed Augur on an “as needed” basis. One stated: “I don’t rely on it, but it does what I need it to do when I use it” (P5)[2]. Two participants actually adopted Augur as their primary scheduling tool. One is an administrator with no other access to his superior’s calendar, and the other is a student who publicized it to interested family and friends. A graph of event accesses during the study period by interviewed participants is shown in Figure 4-3.

[2] Participants are cited by number, e.g. P1 for Participant 1.

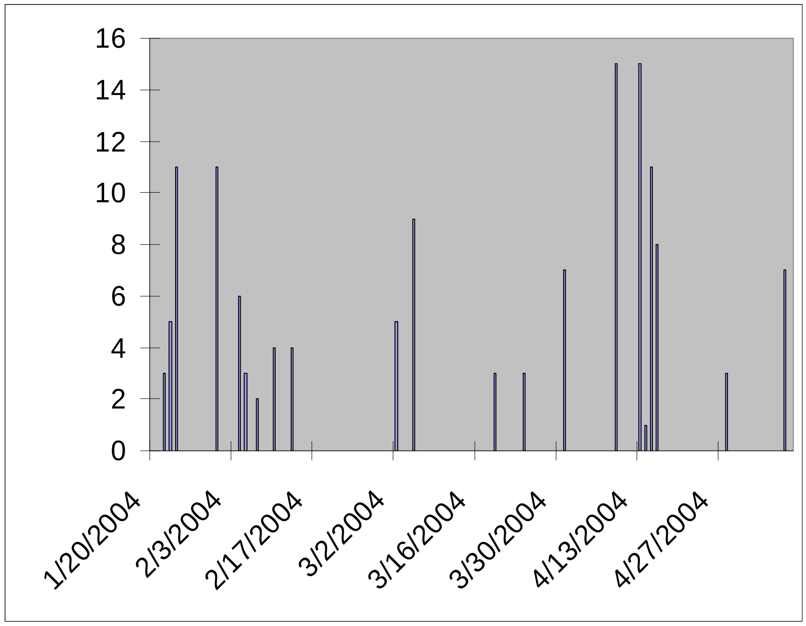


Figure 4-3: Event accesses by interviewed participants by date.

4.4.1. Use categories

Initial expectations for use of Augur included purposes outlined in Palen's 1999 study of groupware calendar use [81]. With the inclusion of predictive features, however, I documented a few other types of use. These observed behaviors are listed below.

"Surfing" – By embedding links to colleague calendars in its user interface, Augur lets users easily jump between these calendars. Participants mentioned a number of instances where they used this functionality to "surf" through colleagues' calendars with no stated motive.

Scheduling – Using Augur to facilitate scheduling was the most popular work-related use among interviewed participants, not surprising given that this is the primary goal of most groupware calendar systems. I will discuss shortly how this task was affected by the addition of attendance predictions.

Finding – Participants described three instances of determining the immediate whereabouts of a colleague using Augur. Predictive information supplemented this process provided that the colleague had an event scheduled at that time.

Orienting – On three occasions, participants reported checking Augur to determine what future events were scheduled. Most users, however, chose to stick with their existing tools for this task due to the convenience.

Diagnosing – The additional forecasting capabilities of Augur served as a source of error for some events. When predictions did not meet user expectations or were decidedly wrong, some participants chose to explore Augur in an attempt to diagnose the errors.

Confirming – Given that Augur presents the same calendar view to the calendar's owner as it does to any colleagues who might look at it, one participant viewed her own calendar in Augur to confirm that it was showing her events properly. In this case, she corrected typos and removed "Dr." from doctor's appointments after confirming the calendar view on Augur.

4.5. Privacy and Impression Management

In sharing their calendars, participants reported many of the privacy management practices described by Palen [81]. Some users renamed appointments to obscure them. Others created appointments to block off undisturbed work time "so you don't look available when you aren't" (P4). One student was surprised at the openness of colleague calendars, saying "I looked at someone's calendar and thought 'I wouldn't share that'" (P7). Others were concerned about those mentioned in their own appointments: "I thought about third parties – does that person want their name shared?" (P9) In general, however, over half the participants interviewed increased the number of events on their calendar, adding more detail and clarity in case someone happened to view their schedule.

Another concern entering the study was the impact that shared, machine-generated inferences of attendance would have on users and the impressions they want to convey [32]. Concerns were voiced by one participant even before Augur's deployment regarding control over the image presented of him to others: "I have control over my self-presentation. I can fake other meetings to control my schedule" (P6). Several other participants listed control over their calendars as the primary benefit of their prior method of scheduling.

Opinions on the accuracy of attendance predictions were mixed. Some participants found the predictions reasonable, while others said that they seemed overly optimistic or were wrong for some events. One claimed that for his advisor, the predictions "made him seem too faithful" (P4) to his calendar. In one interesting case, a student was initially disturbed when he appeared not to attend a particular event, stating that he felt like "the system was taking roll" (P7). He was relieved, however, when he saw that a professor was predicted not to attend the same event, and later said "if there are enough people that don't attend, that's ok."

Augur tended to overstate its predictions of how many users had scheduled the same events. Models of coscheduled events that had performed well for smaller research groups were inadequate for a relatively large user population due to multiple definitions for jargon, acronyms, and initials in event descriptions. One participant described these predictions as "decidedly weird" (P3), while another admitted to being "puzzled" (P9) by them. And while users were quick to notice when a colleague was incorrectly identified as having scheduled one of their events, they did not seem to realize what this observation implied: that they appeared on that person’s schedule as well. Consequently, some users came to distrust this feature and ignore it. However, at least two other users reported exploring Augur in an attempt to diagnose how the system was making its predictions.

4.5.1. Cancellations

After deploying Augur, investigators received several emails concerning attendance reporting. Specifically, participants were concerned about the treatment of events that were either canceled in advance or otherwise disrupted (e.g., other parties in a meeting did not show up). After discussing the problem in interviews, I realized that these worries were due to issues of image. Participants did not want to look like they were doing a poor job of attending certain scheduled events when the reasons for not attending were beyond their control. One participant stated “with certain weekly meetings, I would always go if they were happening” (P5). To Augur, these two cases both represent an unattended event. To users, however, they represent attendance conditional on the event actually occurring.

Table 4-1: Relationship types, the number of pairs studied in interviews, and uses of Augur recorded for each type.

Relationship Type	# of pairs	Traits	Uses
Social	4	Little or no meetings, highly informal	1
Close (copresent)	5	Many meetings, high copresence	7
Close (less copresent)	4	Many meetings, low copresence	7
Less close (aware)	6	Fewer meetings, higher schedule awareness for unplanned meetings	1
Less close (less aware)	5	Lower copresence, lower schedule awareness for unplanned meetings	8
Intermittent	4	Few meetings, highly formal	3

4.6. Use by Relationship

As stated earlier, I examined participant relationships along several dimensions such as meeting frequency, formality, and copresence. Here, I present my classification of these relationships. At a high level, colleague relationships ranged from very close to somewhat detached and intermittent. I examined a total of 28 relationships between pairs of participants. In this section, I characterize the types of relationships found in the study and present examples as to how Augur was used or neglected for each type. The results are summarized in Table 4-1.

4.6.1. Social relationships

A few participants who volunteered for the study had no significant working relationships with the rest of Augur's user base. I was interested to see what use, if any, these people would find for a system like Augur.

Despite having few work-related relationships with any other Augur participants, they certainly have social relationships with many of them. Predictions of attendance had little bearing on these relationships, whose interactions tend to be fixed around unscheduled after-work events or a flexible lunchtime. Consequently, few uses of Augur were reported that concerned a specific pair of social colleagues.

However, a number of participants browsed calendars "for fun" (P8), "out of boredom" (P2), or "out of curiosity" (P3). One student liked to check on her roommate, who was also using Augur, while another published his calendar as a way for family and friends to check in on him. Augur allowed participants to easily browse others' calendars by clicking on the portraits within their events, partially accounting for the high number of "surfing" instances reported in interviews. Some of these instances can also be attributed to novelty effects.

4.6.2. Close colleagues

Nine of the relationships I documented involved colleagues whose offices were physically collocated and who interacted at least twice a week, indicating a greater degree of interdependence. Within these relationships, however, I noticed a disparity between those colleagues who were highly copresent and those who were not. Though their offices are in the same location, a subset of these users is not often in the same place at the same time. I recorded equal amounts of use between both of these subgroups. For those colleagues who are less copresent, Augur provided a source of knowledge that acted as a substitute for the common understanding normally shared by collocated colleagues.

In one student/advisor relationship, for example, the two colleagues work in the same lab space, but due to classes, meetings, and in/out times are typically not in the lab at the same time. Meetings between the two are a mix of both formal and informal interactions. On several occasions, the student consulted Augur to determine a good time in the near future to catch his advisor in the lab for an informal chat. As he stated during the study:

> I was trying to find out where his afternoon event was. I saw that the prediction was green (meaning likely attendance), so I didn't expect to see him in the lab then. (P4)

But what of close, copresent colleagues? As it turns out, the closest colleagues have a number of existing artifacts available for informing one another of their schedules, including paper printouts on doors, shared spreadsheet files, and other web-based calendars. However, nearly all of these artifacts are created at the start of the term and left untouched until the next one. Thus, they lack the detail of a more fastidiously maintained personal calendar, which is more likely to contain non-recurring, special events. Since Augur shares the personal calendar of its owner, it became a last resort resource when face-to-face channels and other calendar artifacts failed.

In one case, a professor could not be found by two of his students. The students were expecting to meet with him, but despite having a high degree of formal and informal interaction with this professor, working in the same lab, and having several alternate schedule artifacts available either physically or electronically, had no idea where he was. A check on Augur revealed that he was at the thesis proposal of another student and likely to attend it. In this case, the additional detail of a personal schedule, combined with an unobtrusive cue to its importance in the form of a color-coded attendance prediction, aided the students by explaining the situation.

4.6.3. Less close colleagues

Colleagues who meet less frequently and whose offices are not necessarily in the same location comprise a second set of working relationships that are less close than those just described. These relationships are characterized by moderate copresence and meeting frequency, and a high degree of informality. Examples include graduate students and their thesis committee members, and labmates with fairly disparate research projects. Eleven of the relationships studied fell into this category, with use of Augur reported for five of them. Interestingly, I found that these five relationships all exhibited insufficient schedule knowledge for coordinating unplanned meetings.

As an example, two participants included a lab manager (an administrative position) and the professor who supervises the same lab. Their working relationship, which involves scheduling and preparing for lab demonstrations, tours, and meetings, requires occasional interaction. They reside in different buildings, but have a standing meeting as well as intermittent email communication. The professor has a number of other responsibilities which frequently delay the standing meeting. Thus, the meeting has taken on more of an informal quality, as its timing is very flexible from week to week. The lab manager describes a typical occurrence before Augur was fully deployed:

> Last week was fairly typical. [The professor] missed our Friday meeting. I stopped by the office, he wasn't there. So then I went to another meeting in the same building. I came back and he was there. (P10)

Therefore, the lab manager employed Augur to determine a good time to make the 20-minute trip to the professor's building the day of their meeting rather than showing up at the oft-missed standing meeting time. In this case, predictions served to indicate good times to stop by the professor's office.

4.6.4. Intermittent colleagues

Finally, about four of the relationships I studied involved colleagues who have infrequent, formal meetings and otherwise have no other interactions. While these colleagues have poor knowledge of each other's schedules, their work is not highly interdependent, making this kind of knowledge less necessary. Consequently, few uses were reported with respect to these relationships, and the additional capabilities of Augur provided little benefit to them. Those uses that were reported were primarily out of curiosity over another colleague's schedule that had previously been a black box.

As an example, one professor's only colleague on Augur was another professor who he saw at a weekly faculty meeting. Outside of this meeting, the two had little or no interaction and work in different buildings. In the rare cases when an individual meeting between them was needed, his coordination method was simple and sufficient: "If I need to meet with him, I'll talk to him at the weekly group meeting and I can mentally compare calendars" (P11). In the case of these two professors, their working relationship is sufficiently distant that they can work purely from scheduled meetings. For them, a system like Augur provides no benefit over a standard calendar application.

4.7. Home and work

In their work on domestic calendars, Crabtree *et al*. [18] make the following observation about Augur:

> We would suggest that the design of [groupware calendar systems] needs to consider supporting the negotiation of schedules when moving from the workplace to the home. This is not to criticize Tullio *et al*., it is only to recognize that the needs of the home are different to the needs of the workplace: predicting event attendance and making members aware of who else is attending a scheduled event is not a pronounced feature of calendar use in the home, whereas negotiating schedules evidently is.

In my study of Augur, there are indeed substantial differences between work and home calendars that reduce the utility and effectiveness of predictive features. Perhaps the most important factor was the *shared responsibility* of many family events. For example, one participant made entries for his children's activities, but was not always responsible for attending them. Other participants copied events onto their schedules from their spouses' calendars to stay aware of one another. In these cases, it was difficult for colleagues to determine exactly who was responsible for attending these events. Regarding his advisor, one participant said, "It's hard to tell whether he or his wife is going, and I can't really ask because it's personal stuff" (P5).

It is precisely this shared responsibility that motivates the need to support schedule negotiation in domestic calendars, as Crabtree *et al*. prescribe. Yet Augur does not directly support this type of negotiation, and essentially assumes it has already occurred by the time it starts making predictions about future attendance. To Augur, attendance at a calendar event is the owner's responsibility, and there is no notion of a shared event. Moreover, the workplace coordination tasks that Augur was designed to support do not necessarily overlap with coordination tasks for the home. In summary, the study found concrete support for Crabtree *et al*.'s suggestions.

Nevertheless, home and work calendars affect one another. Colleagues find it useful to know when home constraints are present. For example, one user noted that family events were present on a professor's calendar one afternoon and realized that any chats that afternoon would be cut short by the event. Likewise, a handful of Augur users asked for accounts that would allow their spouses to view their schedules. Thus, there is work to be done in providing the right kinds of support to family and colleagues across both types of schedules.

4.8. Discussion

4.8.1. Who benefits the most?

There is no doubt that the participants who benefited the most from Augur were students and staff, its most frequent users. In fact, of all the relationships examined during interviews, the most frequent instances of browsing, scheduling, and finding involved student-professor relationships where the professor's schedule was the calendar of interest. This reinforces Grudin's observations in industry, which found that calendar browsing was typically directed up the organizational hierarchy [37].

In this study, colleagues with more intermittent, formal working relationships tended to have less use for Augur. In these cases, it seems that work interdependence was low enough that the informal, opportunistic communications supported by Augur were less necessary. On the other extreme, social "surfing" of calendars was supported to some extent by Augur's support for easy calendar viewing, but little use was found in terms of work.

Augur seemed to provide the most help to close working relationships and less close relationships with a diminished ability to coordinate unplanned meetings. For close relationships, Augur's additional information occasionally offered value over existing coordination tools, while for less close colleagues, it made up for a lack of existing intuition of each others' schedules.

4.8.2. Exceptions

In expressing their degree of trust in Augur's attendance predictions, participants often qualified their ratings with references to uncharacteristic or unforeseen circumstances. For instance, during the study period, one participant was injured and out of work for one week, while other participants experienced occasional sick days.

In addition to these unexpected events, participants also experienced disruptions in their schedules from periodic or long-planned events. In one case, a participant had a baby during the latter half of the study. In another example, trust in attendance predictions dropped during the final weeks of classes, when final exams and projects were on the forefront of both students' and professors' minds, with one student observing "During finals week, I'm inferring schedules more than looking at them" (P13).

Of course, one of the objectives of Augur is to infer when special events will be attended over conflicting routine schedules. However, the difficulty with these exceptional cases is that schedules were in large part *not* altered. Augur cannot predict attendance for events that are not present in the calendar. Predictions near the end of the study period thus decreased in value dramatically because, as one participant put it, "at the end of the semester people are skipping things left and right" (P7).

In some cases, calendar owners made up for these disrupted schedules by using other methods for publicizing these occurrences, such as a "heads-up" email before the event, or in person during meetings. One participant complained, "If they aren't there at 10:00am then where are they?" (P10), implying that although Augur can predict when an event will not be attended, if the calendar is incomplete, it cannot offer an alternate location for that person.

It is important for designers to realize that forecasting groupware systems which draw their predictions based on past behavior patterns will likely encounter these exceptional cases. Conventions such as “heads-up” emails can compensate for some of the coordination problems that may occur, and designers should consider how best to support this practice such that any interested, permitted party can stay informed. Another option is to expose more of the available input to other users so that they may draw their own conclusions, as in MyVine [28] or Fingerprint [13]. This solution, of course, comes with the risk of sharing private information.

4.9. Discussion

As stated earlier, I was interested in user reactions to the “black box” nature of Augur’s inferences. While users had control in the sense that attendance reports and the calendar events themselves influenced Augur’s predictions, the mechanics of these influences were not detailed to them beforehand. Thus, I found several instances of diagnosis behaviors in interviews, with users either asking about the reasoning behind Augur’s predictions or volunteering their own explanations for the effects they were observing.

Along these lines, the fact that some participants expressed concern over their appearance to others through Augur demonstrates that steps should be taken to ensure that users retain control over this shared image. I have considered the addition of overrides into Augur whereby users can set their own predicted attendance as needed. Similar mechanisms have been suggested in and [5] and [28].

Mitchell’s CAP system [74] exhibited poor performance during the large schedule disruptions caused by the semester boundaries in the academic year. Since the learned probabilities from the previous semester associate availability with event dates and times, one can consider mapping these probabilities to the dates and times of new events on next semester's schedule. This could at least establish a baseline and possibly shorten the learning time required to produce sound predictions about attendance.

It may be useful to train separate models according to job description. Fogarty *et al.* have had good results generalizing models trained on one set of users to other workplaces [27]. In the case of Augur, identical events mean different things to different job descriptions. A class, for example, may be more easily missed by a student than by the professor that teaches it.

The original version of Augur, as described in Chapter 3, contained elements in the user interface that could tell a user how many times their calendar events had been browsed by others. This feature was removed to simplify the interface and allow more focus on the effects of the attendance and event matching predictions. In retrospect, this facility could have been left in the system to encourage more use among participants and promote awareness of how their personal information is being shared.

In summary, the predictive capabilities of the Augur system had an impact on the use of what otherwise would have been a traditional groupware calendar system. Inferences about which users had scheduled the same events had the unexpected effect of encouraging exploration and organizational learning, while predictions of attendance showed sporadic utility in facilitating communication between users. In addition, I noted the implications for privacy and impression management that arise when such inferences are shared amongst a group, and stress that designers be sensitive to these issues as presence and availability forecasting tools find their way into mainstream applications.

The next chapter examines these issues of privacy more deeply and extends the results to the broader class of presence and availability forecasting systems.

Chapter 5: Privacy in forecasting groupware

In this chapter, I turn to the problem of accommodating privacy in groupware applications that support presence and availability forecasting. As described in the previous chapter, the field study of Augur reported a number of participant activities focused on managing privacy. In addition to those behaviors previously observed in traditional shared calendars, participants also took actions to either diagnose or alter the predictive capabilities of Augur as a means of controlling their personal information. To further explore how the addition of predictive capabilities affects the privacy implications of a groupware application, I present a detailed analysis of Augur based on a structured method developed by Jensen *et al*. [53] that examines system goals and identifies potential privacy vulnerabilities in the execution of those goals. A follow-up classroom study uses this method along with a heuristic method developed by Bellotti and Sellen [10].

5.1. Privacy in groupware calendar systems

Privacy with respect to groupware calendar systems has been studied most extensively by Palen [81], Grudin [36], and collaboration between the two [83]. While their studies were not specifically seeking to address privacy, they found that privacy has a substantial impact on the adoption, use, and evolution of groupware calendar systems with their users.

Early studies by Mosier and Tammaro [76], as well as Kincaid and Dupont [59], found that schedules were typically shared only between managers and their secretaries, and occasionally between managers. In settings where shared calendar use was more prevalent, Grudin found that individual contributors to whom no one reported regarded calendar sharing as an opportunity to be micromanaged, preferring to share only free/busy times. Executives refrained from sharing their schedules due to the sensitivity of the information they contained. However, managers and administrators exhibited the highest degree of sharing, characterized by high levels of trust and perceived benefit. This balance between privacy and benefit is summarized by Grudin [36]:

> Just as people who live in buildings with paper-thin walls may adopt a convention of ignoring what they cannot help overhearing, people who allow open access to their calendar details assume that people will access information only when needed and would be offended by an inquiry that revealed "snooping." Being able to block off a calendar entry or reserve a conference room is deemed an adequate balance. Privacy is ultimately a psychological construct, with malleable ties to specific objective conditions.

Mechanisms must exist to protect privacy no matter how rarely they may be used. It is the presence of these facilities that reduces the perceived risk to users. In the case of Augur, privacy management occurred within the individual calendaring habits of participants, such as the omission of sensitive events, cryptic or context-sensitive naming of events, reciprocity of access settings, or defensive scheduling to regulate interruption. Other mechanisms were explicitly designed into the system, such as access-control lists and private flags on specific events.

Default settings can have a sizable effect on the privacy preferences of the workgroup or organization. These behaviors are typically not changed by users and over time can become institutionalized into the organizational culture. The users of systems with different default sharing policies can have radically different perceptions of what constitutes appropriate disclosure of information. In the Augur field study, participants were accustomed to an open, academic setting where there were few reasons to withhold information. Therefore, Augur quickly became open when most participants consented to sharing their calendars with all other Augur users.

5.2. Motivating privacy analysis with the field study

When Augur's predictive facilities were introduced, the automated nature of those predictions presented a loss of control over the information associated with participants' calendars. Once it became clear that the predictions were not perfect, some participants cited either frustration or bafflement at how their calendars appeared. In response, those who viewed the predictions as poor would discount them, compare their predictions to others to find safety in numbers, or attempt to diagnose the source of the error. When event matching algorithms did not perform as expected, participants did not seem to be troubled by the fact that an improperly matched colleague on their calendar implied that they were reciprocally present on that colleague's calendar.

Participants did not report many issues with respect to security. Augur was constructed to use authentication, SSL encryption, password-protected databases, and password-protected synchronization, but nevertheless had some vulnerabilities with respect to cookies and unencrypted FTP/HTTP synchronization. Participants did not seem concerned, and even opted to use easy-to-remember, but potentially guessable passwords in most cases to access their accounts. This does not mean that security is an unimportant issue. Privacy is not an active goal for most users. Certainly, had the database been compromised, concerns would have been much greater.

The cultural norms of the academic department where the field study was conducted have a great deal of bearing on the privacy response to Augur. The relatively open research environment was reflected in the privacy-protecting behaviors of participants. Voluntary participation, relatively insecure passwords, a willingness to share schedules with any Augur user, and only minor concerns about the accuracy of predictions illustrated how individual differences in users and groups can influence the importance attributed to potential vulnerabilities. Moreover, the benefits of being accessible and more easily communicating with colleagues outweighs the loss of some privacy. While this does not affect the presence or absence of vulnerabilities, it certainly affects the design of solutions implemented to mitigate or eliminate them.

In light of reactions to the introduction of attendance and matched event predictions, I sought to analyze what additional vulnerabilities might have been created by Augur's features, and what implications the results might have for other forecasting groupware systems.

5.3. Approaches to privacy analysis

Heuristics and guidelines have been proposed to help guide designs for managing privacy [10, 62]. Guidelines provide support to designers by giving them a framework for detecting and addressing potential privacy violations before the system is implemented and deployed. However, these heuristics, while building on a wealth of experience, imply the existence, or the desirability of seeking a universally satisfactory solution.

Recent work in the domain of privacy has characterized privacy management as a situation-dependent, dynamic process involving the negotiation of boundaries and the management of information disclosure [82]. Given this view, it becomes very difficult to derive a universally acceptable solution. Instead, designers should seek to identify potential vulnerabilities, then either identify solutions or mitigate where solutions are not available.

I will present analytical results from each of these two perspectives. The guideline-based approach by Bellotti and Sellen [10] was applied to the Augur design by HCI students and focuses on the design's feedback and control mechanisms. In addition, a structured technique called STRAP is used to analyze Augur using a goal-based perspective that is capable of refinement as users find new applications of the system or as the designers introduce or modify functionality. This analysis was performed by myself and Carlos Jensen, then later by HCI students in a classroom experiment.

I chose to subject Augur to multiple analyses for several reasons. First, no validated technique for performing privacy-aware design yet exists. Bellotti and Sellen's work, however, offers a frequently-cited set of design guidelines that have been well-received by the research community. STRAP, on the other hand, offers an analysis technique rooted in more recent thinking about the nature of privacy management. Second, these different perspectives were likely to generate a potentially disjoint set of vulnerabilities that can be combined into a more complete set of issues to be considered in the Augur design.

5.4. Privacy analyses of Augur

5.4.1. STRAP

STRAP (for Structured Analysis of Privacy) was developed to account for the flexible, dynamic nature of privacy management described by Palen and Dourish [82] as well as Adams [1]. It consists of four steps that can be applied repeatedly as the system's functionality or possible uses change: Analysis, Refinement, Evaluation, and Iteration. Analysis involves first defining the goals of actors involved with the system, which includes both users and the components of the system itself. Refinement involves mitigating or eliminating vulnerabilities by putting constraints on the information used or changing the goal structure. Evaluation allows for the comparison of multiple design alternatives leading to an ultimate choice. Iteration accounts for the addition of new functionality or changes in goals by repeating the analysis to incorporate these changes. For the purposes of this chapter, I will focus on the analysis step only, since Augur is already a designed and deployed system.

An essential component is a goal-oriented analysis of the system. By examining a system in terms of goals achieved by actors, the analysis incorporates both higher-level user tasks and system implementation choices. Obstacles to completion of goals are in this context considered privacy vulnerabilities. Thus, STRAP allows for the identification of high-level architectural vulnerabilities that may find their way into the execution of a number specific tasks by users.

As part of the STRAP analysis, I first derived a goal-tree for Augur. In the goal-tree, goals and sub-goals are drawn as circles, the top decomposed into lower level circles, as denoted by the arrows. Actors responsible for goals are typically identified by color-coding the nodes. Arcs along the paths denote an ‘or’ operator, and while the ordering of the children left to right does not necessarily denote order of operation, the diagrams shown in this chapter accommodate that reading. Vulnerabilities are drawn as clouds with a callout describing them, and are placed on the path of the goal they block. Sub-goals sometimes refer to each other recursively. For the sake of brevity, these sub-goals are marked in bold and the sub-trees omitted.

At each goal and sub-goal, the following questions are asked:

- What information is disclosed/transmitted, and to whom?
- What information did the user receive, was consent obtained, and how?

- What is done with the information, how is it stored, and for how long?

Vulnerabilities are then classified into one of four categories derived from the 1973 Fair Information Practices (FIPs) [95]:

1. Notice/awareness: *“Consumers should be given notice of an entity's information practices before any personal information is collected from them.”*
2. Choice/Consent: *“[…]giving consumers options as to how any personal information collected from them may be used.”*
3. Integrity/Security: *“[…] data [should] be accurate and secure.”*
4. Enforcement/Redress: *“[…]privacy protection can only be effective if there is a mechanism in place to enforce them.”*

In this chapter, I will first examine the high-level decomposition of Augur goals, then address each sub-goal in turn.

5.4.1.1. High-level goals

Users of Augur perform several sub-goals with Augur under the general goal of group calendar use. While some goals, such as logging in/logging out and the completion of the attendance diary, are for the most part instituted by the system design, others are more directly related to the needs of calendar users as described in Chapter 2.

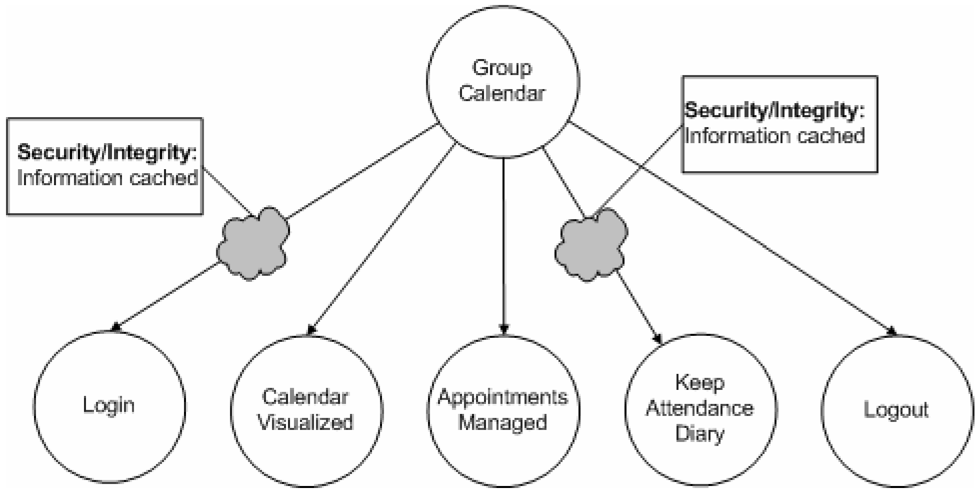


Figure 5-1: Top-level goal tree for Augur.

Aside from the attendance diary, the overall goals reflect a similar set of goals to traditional groupware calendar systems. Many corporate systems involve either a one-time or persistent login process to access the employee address book, or automatically login to the calendar system when a user logs into his/her workstation. Viewing and managing calendars are the primary functions of such systems. Although the data contained within calendars is often integrated into suites of workplace applications and used toward their goals, Augur has no such integration. In addition, administrative duties such as user management and software maintenance have been left out. Vulnerabilities exist at this level because, as a web-based application, data is subject to caching by the browser and may therefore remain persistent longer than users expect.

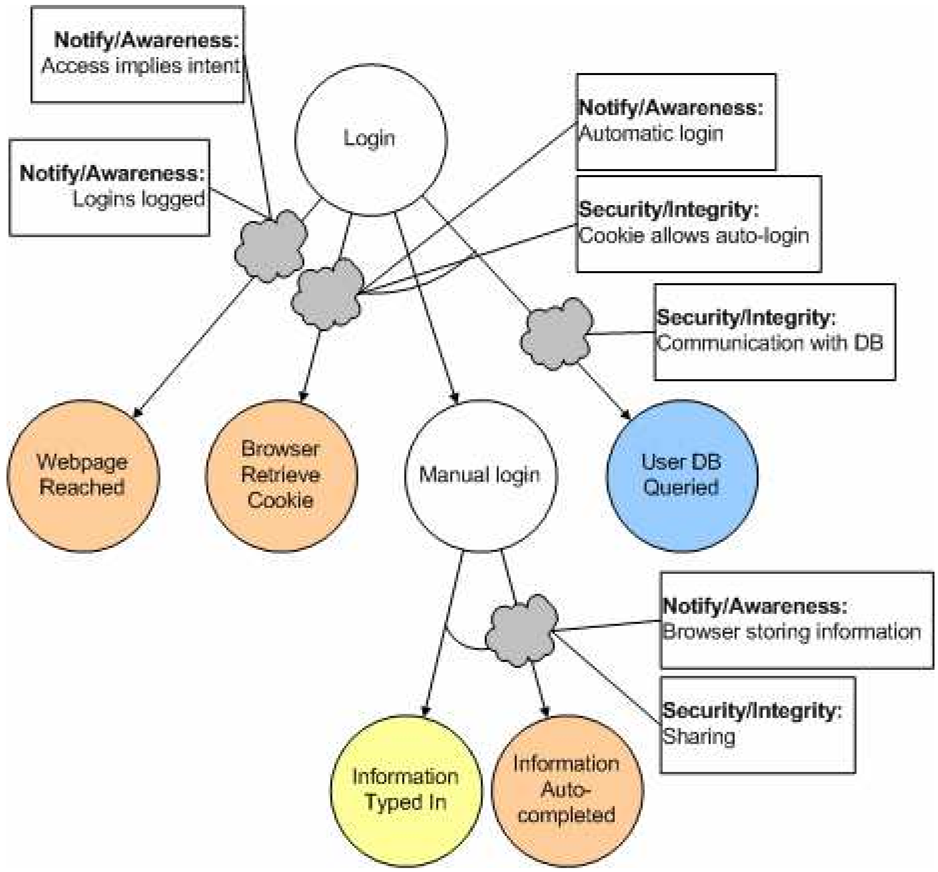


Figure 5-2: Goal tree for the Augur login process.

5.4.1.2. Login

The login process for Augur is not unlike that of most common web services. The web-based nature of Augur differentiates it somewhat from traditional calendar systems. Augur's security is rooted in the web-based mechanisms such as SSL, cookies, and database queries from servlets rather than back-end or OS-level security implementations.

Goals are achieved either through manual login or by retrieving a persistent cookie from the user's browser and matching it to a key in the user database. Vulnerabilities in this goal are primarily created by issues of data security. For instance, the browser and database both store login information that could potentially be used for access by others. In addition, if the computer is used by multiple people, they may have access to this data, making it a bad idea for users to opt for automatic login on public computers or to refrain from logging out after they are done using Augur.

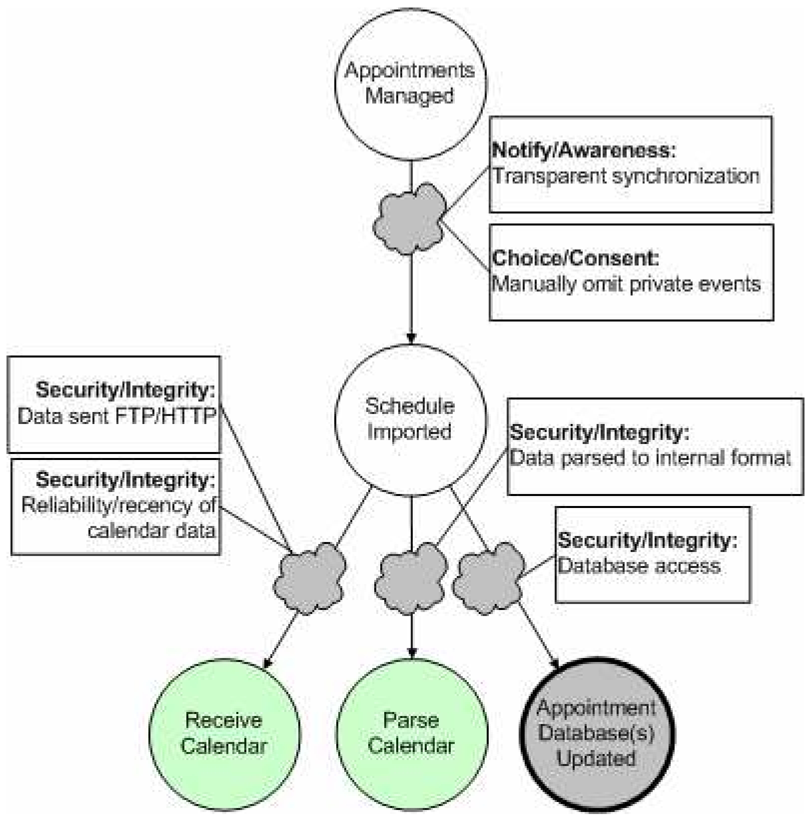


Figure 5-3: Goal tree for appointment management in Augur.

5.4.1.3. Managing appointments

Augur differs from most calendar systems in that it provides no facilities for the editing or addition of new calendar events. Rather, these functions are performed by users on other calendar applications, such as PalmOS devices or desktop applications such as Outlook or iCal, prior to being uploaded to Augur's server. Therefore, appointment management is a mostly transparent process to most users. While from a user's perspective, little takes place in the achievement of this goal, vulnerabilities exist in terms of notification, consent, and security/integrity. The synchronization process occurs with little or no notification depending on the source application, and little control is provided over what events are synchronized other than those marked with a 'private' flag. In addition, the data provided may be more or less accurate depending on the frequency of synchronization or the scheduling reliability of the user. Lastly, data is transmitted over FTP or HTTP and parsed into an internal format, meaning that information could be intercepted during transmission or lost during the parsing process.

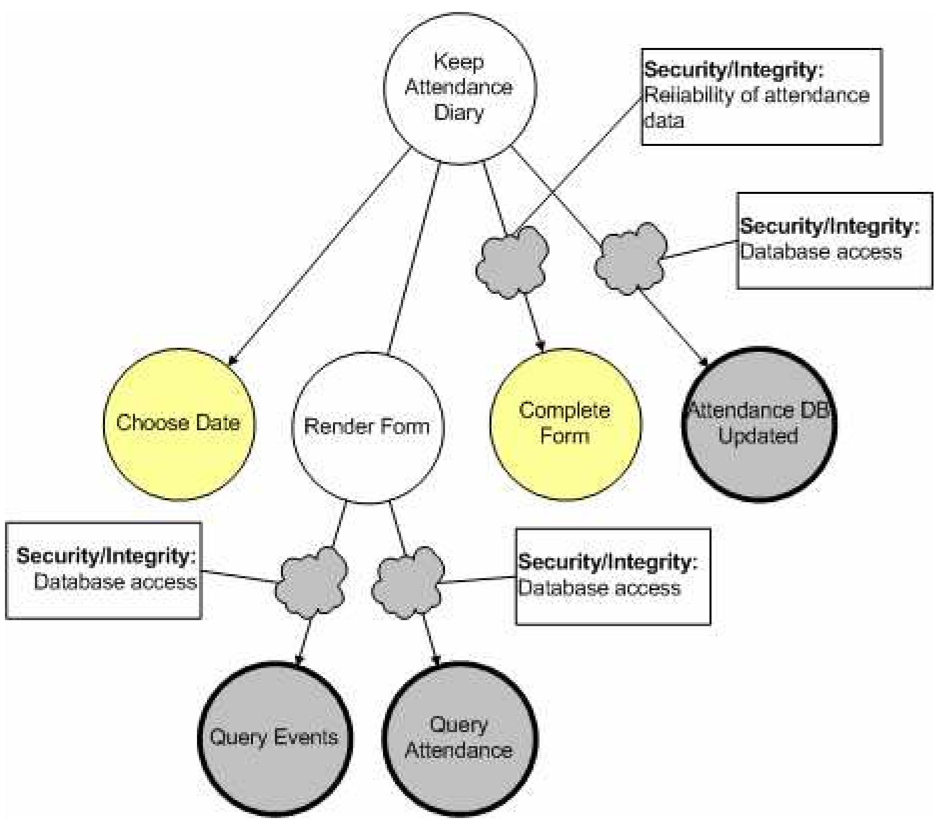


Figure 5-4: Goal tree for the Augur attendance diary.

5.4.1.4. *Attendance diary*

Completion of the attendance diary is a straightforward process unique to Augur, with users completing and submitting a form. Internally, the retrieval of events, along with the transmission of data to the Augur database, present vulnerabilities with respect to data integrity and security. Augur's use of an SSL connection and password-protected database serves to mitigate these concerns. In addition, there is no way to ensure that the attendance data provided is accurate. This has both advantages and disadvantages, as I mention later when discussing the integration of location tracking into Augur.

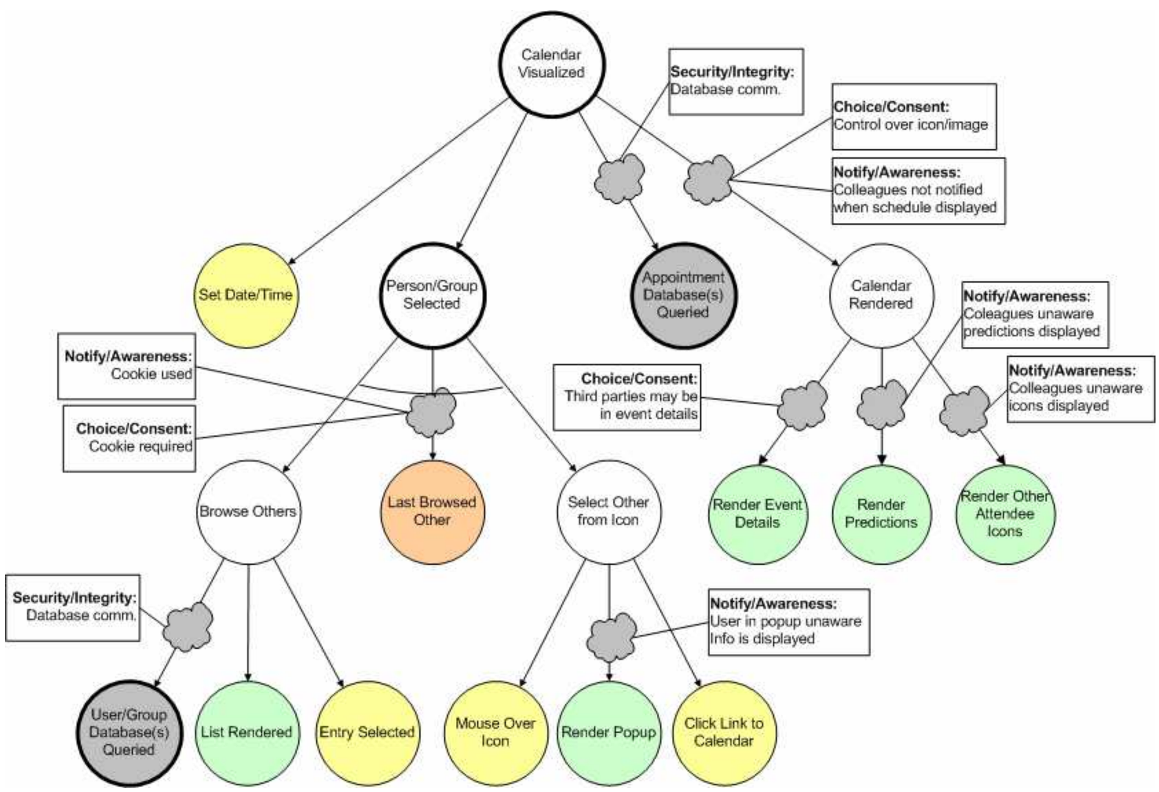


Figure 5-5: Goal tree for Augur's calendar visualization.

5.4.1.5. Visualizing the calendar

The goal of viewing calendar data is the most important one in Augur, and serves to fulfill most of the tasks undertaken by groupware calendar users as observed by Palen [81]. In addition to scheduling meetings and reminding him about the day's events, a user can also estimate the time use of others and initiate informal communication in the form of ambushes. The goal-tree for viewing calendars is necessarily larger than other sub-goals.

At a high level, a user chooses a date and a person whose calendar to view that may be herself. The system then retrieves the information and renders it. While choice of date is a simple process, Augur offers several options for choosing the calendar viewed. The user's own calendar is of course always present, but a side-by-side view of another calendar can be obtained by either selecting a person from a list or, if they have co-scheduled an event, by selecting their icon from the event cell. Lastly, a cookie remembers the last colleague selected and presents that person's calendar in future views until another person is selected or the colleague calendar is closed.

As with the other user goals, persistent data such as calendar event information presents a vulnerability in terms of data security. However, new issues of consent and awareness arise when user calendars are visualized. For instance, users are not aware when their calendars and attendance information are visualized to others, or to whom. They only know that they have given *permission* to do so through Augur's access-control facilities. Not only does this apply to the browsing of colleague calendars, it is also present in co-scheduled events that are displayed in the user's own calendar in the form of colleague icons and pop-up menus. Next, third parties mentioned in the descriptions of calendar events are unaware that they have been mentioned in another person's calendar unless they 1) have permission to see that calendar and 2) take the time to view the calendar to see their identity mentioned.

In rendering calendars, Augur offers a very constrained view; there are no options for weekly/monthly views and no support for viewing events by category at different levels of detail. However, although Augur users have the option of choosing their iconic representation, no explicit controls are present in the interface for doing so; users must contact the administrator. So some choice/consent issues here warrant additional facilities for letting users control this aspect of the UI.

Lastly, the use of a cookie to remember the last colleague browsed presents issues of notification (the cookie is implicitly stored) as well as consent, since it is created to enable colleague-browsing functionality.

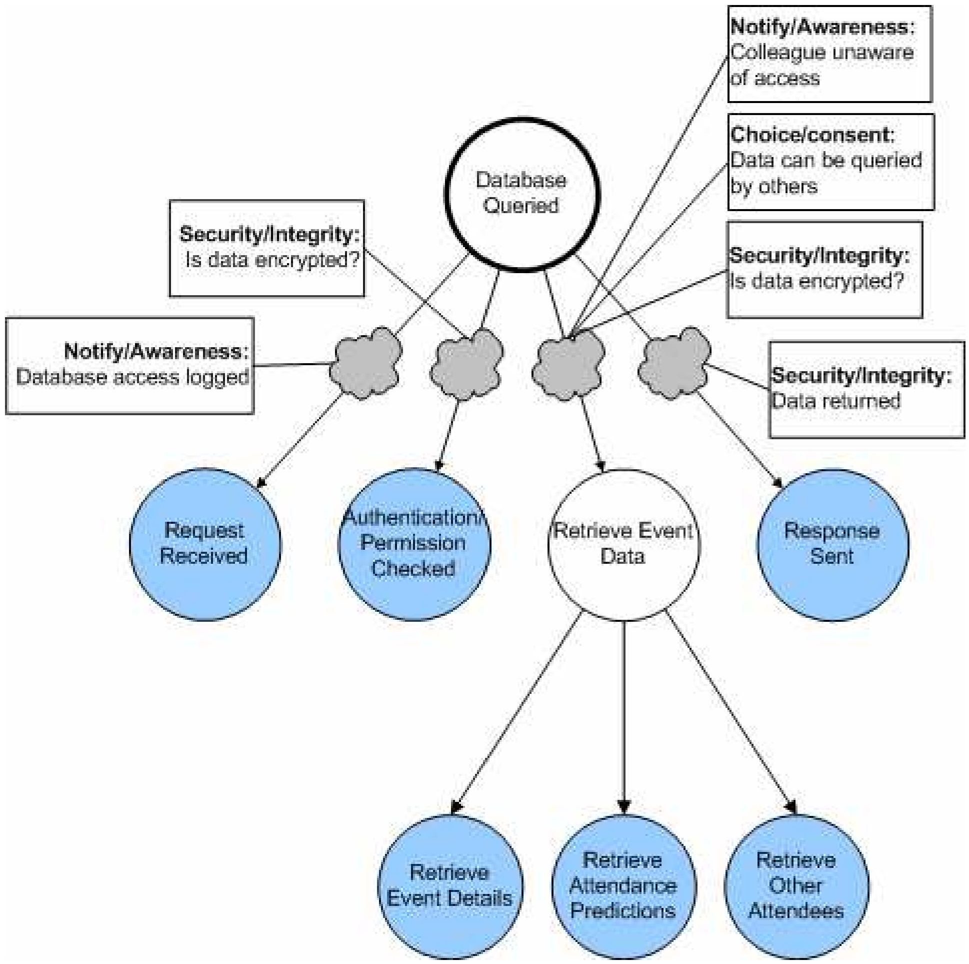


Figure 5-6: Goal tree for database queries in Augur.

5.4.1.6. Database queries

Any goals involving the browsing of calendars, including the completion of the attendance diary, must at some point query the Augur database for the required information. A query to the Augur database, of course, presents a number of sub-goals requiring data transfer. The query itself is of a request/response form, each of which requires data exchange. In addition, each query requires permission to access the database, so some authentication must occur. Lastly, the calendar event information, including attendance predictions and information about co-scheduled attendees, must be retrieved. While most of these exchanges present only concerns with the security and integrity of the data, it should be noted that colleagues are not notified when their data is retrieved at the request of another Augur user.

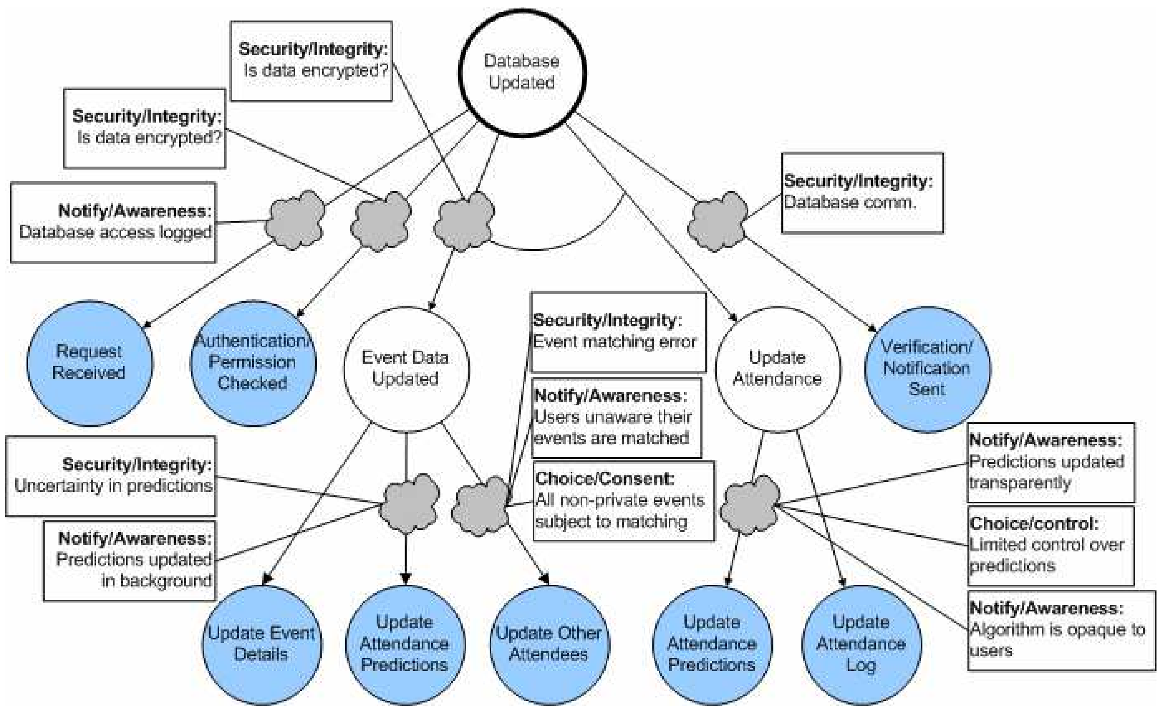


Figure 5-7: Goal tree for database updates in Augur.

5.4.1.7. Database updates

At the heart of Augur's functionality is the process of maintaining an up-to-date database of calendar events complete with predictive information about attendance and co-scheduled events. Goals involving the synchronization of schedule data as well as training data collected by the attendance diary require the database to be updated for their completion. Similar to database queries, issues of security arise in the request/notification format of database updates and the authentication procedures that allow the updates to take place.

A number of interesting vulnerabilities arise, however, in the actual mechanisms that update Augur's calendar information. For instance, the event matching and attendance prediction algorithms present issues of data integrity. Since both of these functions have an inherent degree of uncertainty, they are not guaranteed to be 100% accurate. Therefore, the database may contain inaccurate representations of attendance likelihood or co-scheduled events.

In terms of how users are made aware of data updates, attendance and co-scheduled event predictions are updated upon any changes in a user's schedule or attendance information without explicit notification. Moreover, users who are matched to the events of others are not notified that they have been linked to another's schedule. Finally, users are not explicitly made aware of how Augur's algorithms are using the data they have provided to arrive at its predictions.

Participation in Augur means that predictions are generated for any non-private events scheduled by its users, so choice and consent are limited somewhat in order to boost participation. Consent is also constrained in that users have little control over Augur's predictive algorithms outside of the attendance diary. As I shall describe in Chapter 6, this limited control can also affect their ability to correctly understand how Augur's predictions work.

It should be noted that for the purposes of study, database accesses and updates as well as login/logout information were collected and stored. While this data collection presents vulnerabilities by persistently storing personal use information with little notification that it is doing so[3], it is not a goal that would otherwise be in a production system. Therefore, its relevance to the overall privacy analysis is minimal.

5.4.2. Summary of vulnerabilities

Using this analysis, a few major categories emerge in terms of potential vulnerabilities.

Data security: From database queries and storage to HTTP and FTP data transfer to the login process, points of data transfer are vulnerable to being compromised. Fortunately, encryption and access control can serve to mitigate these kinds of concerns. Browser-based vulnerabilities, however, such as cookie management, caching, and automatic login preferences, require some diligence on the part of the user. Lastly, safeguarding of private events requires the most care from users. Augur does not assume events are private by default; those events that are private must be marked so by users. It should be noted that this is a typical convention in most calendar systems.

Integrity of calendar/attendance diary: While Augur was designed in part to mitigate the effects of inaccurate shared calendars on workplace communication and coordination, the algorithms used by Augur depend to some degree on the quality of the data provided to function properly. Certainly, Augur can accommodate inaccurate recurrence boundaries, event conflicts, and other issues as described in Chapter 3. However, stale, sparse, or defensively maintained calendars present challenges beyond its capabilities. Likewise, inaccurately maintained attendance data cannot be accounted for by the system. It should be noted, though, that less flexible mechanisms that eliminate

[3] It should be noted that Augur users were made aware of this logging in the consent form they signed prior to the study.

inaccuracies may serve to inhibit a user's ability to control their accessibility through the calendar.

Notification and consent to browsing: A great deal of Augur's functionality takes place "behind the scenes". Calendars are synchronized transparently where possible. Attendance predictions and co-scheduled events are determined automatically upon any change to a user's schedule. In addition, consent to make these predictions is implicit, a requirement to participate in Augur. While this policy is intentionally designed to promote use, it does take some choice away from users in controlling the dissemination of their personal information. It is an open issue whether such predictive features should be enabled or disabled by default. Third parties mentioned in calendar events, meanwhile, are now associated with the predictive information of those who entered their identities into event descriptions.

In addition, as with most groupware calendar systems, notification is not provided when user information is displayed to colleagues during the process of calendar browsing. Although a component was originally incorporated into Augur, providing this kind of social translucence has not yet been evaluated. However, it is somewhat encouraging for promoting system use and privacy management by demonstrating to users that their calendars are being viewed.

Predictive integrity: The greatest distinction between Augur and traditional calendars is, of course, its augmentation of the calendar with predictive information. The uncertainty present in these predictions is itself a vulnerability. The user goal of viewing a colleague's schedule, and all the purposes it entails, such as estimating availability and location, is hindered by inaccurate predictions. Approaches such as bootstrapping and supervised learning have been implemented in other systems to mitigate these vulnerabilities.

5.4.3. Augur compared to a traditional GCS

The STRAP analysis of Augur illustrates a number of privacy concerns that are also shared by both traditional groupware calendar systems. Vulnerabilities related to data security, stale or inaccurate calendars, and login information are all present in commercial systems. What sets Augur apart is the predictive information it adds, as well as the secondary effects of this functionality.

For instance, consider third-party privacy. In traditional calendars, users may schedule an event that discloses a person's identity in the description. In Augur, this particular vulnerability has the potential to be instantiated automatically. The event-matching algorithms associate events with other users and display them given the required permissions. Control over this algorithm is indirect, affected only by trial-and-error editing of event descriptions. Such a feature may be undesirable in an internal job interview, for example. Also, the event matches may not be accurate, incorrectly associating users with some events.

Likewise, attendance predictions are generated automatically by a mechanism that is opaque to users. Although some control is provided in the form of the attendance diary, neither direct control nor a detailed awareness of the algorithm is available. Though the facility is provided as an augmentation to traditional calendar data, it is somewhat dependent on the integrity of this data to function properly. Beard *et al*. [3] discovered that users were uncomfortable sharing manually-assigned priority levels associated with each of their scheduled events. While Augur's predictions could be construed as priorities, they are also machine-generated, shifting the responsibility to the system rather than the person.

Whereas traditional calendars present only schedule information as a representation of colleagues, Augur also has iconic representations of users in addition to predictive information. Thus, more detail is provided than a typical calendar, necessitating more control through customizability.

Palen and Dourish note that even the temporal and sequential patterns exhibited by shared calendars can inadvertently compromise privacy [82]. Augur's inability to provide more high-level views of schedules leaves it somewhat less prone to this type of vulnerability, but the field study in Chapter 4 seemed to indicate that the benefits of such facilities would offset such an issue.

5.4.4. A classroom study of privacy and Augur

As part of a separate research project investigating the effectiveness of STRAP, a classroom study was conducted to generate privacy analyses using both a guideline-based approach as well as the goal-directed approach used by STRAP. Thirty-two college students in an undergraduate HCI class were provided with a description of the Augur system (Appendix C) as well as some screen shots of the system in use. Half of the class analyzed Augur using STRAP, the other using Bellotti and Sellen's method. Students were aware that their performance on this task would not be linked to their course grade. A brief description of Bellotti and Sellen's framework is described below.

5.4.4.1. Bellotti and Sellen’s guidelines for privacy-aware design

The design and deployment of the RAVE system [30] led to the development of Bellotti and Sellen’s framework for privacy-aware design in ubiquitous computing. This framework has undergone changes and refinements over the years. Below I describe its most recent incarnation [10].

First, the designer asks a set of questions about the proposed system to let the designer identify, evaluate, and mitigate or eliminate potential privacy problems:

- What information is captured and how?
- What happens with this information?
- How is this information made accessible to the user?
- What is the purpose of the information collected?

The designer then identifies the core problems and comes up with a way to address them. Criteria such as trustworthiness, perceptibility, flexibility, and accountability are used both as a set of guidelines for what a desirable design should contain, and a set of benchmarks against which potential solutions are evaluated.

5.4.4.2. Results

By framing the analysis within two frameworks formulated from differing perspectives on privacy, the classroom study provided some insight on how potential users think about privacy when shown a novel system.

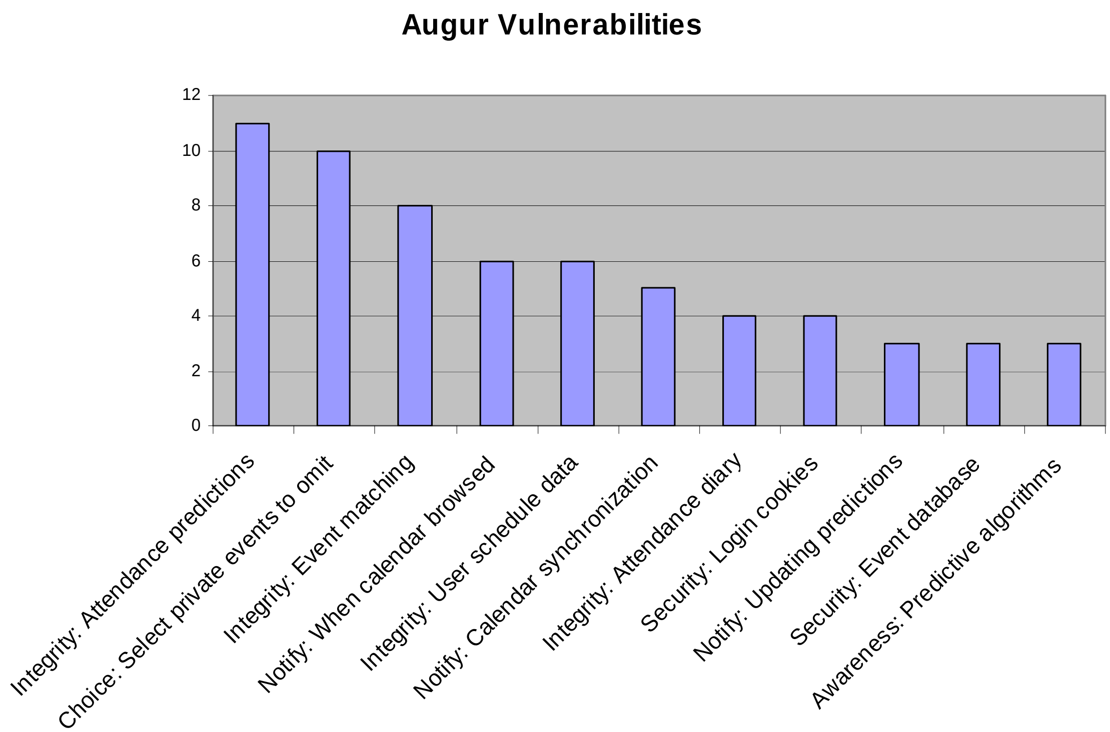


Figure 5-8: Augur vulnerabilities listed by the number of times they were cited in the classroom study.

Examining a graph of vulnerabilities found Figure 5-8, it is clear that the students were most concerned about the integrity of Augur's predictive facilities, although for the STRAP analysis, the vulnerabilities found are more evenly distributed[4]. While the STRAP analysis presented earlier identified 48 vulnerabilities, this graph shows that only 22 were found by students. However, the vulnerabilities "missed" in the student analysis primarily concerned security issues with data transfer. One notable omission in the classroom study was the problem of including third parties on scheduled events without their knowledge or consent. Interestingly, though, the problem of automatically

[4] Note that students who performed the STRAP analysis did so in groups. In Figure 5-8, a group's citing of a vulnerability was only counted once.

associating third parties with events was identified by two students. While some vulnerabilities are certainly of high concern from different perspectives, this demonstrates how different vulnerabilities can be found using multiple analyses.

5.5. Privacy and forecasting groupware

Other work is just beginning in terms of examining the implications of predicting future user states. Smith *et al*. [90] are taking the approach of building applications with obvious privacy concerns and deploying them to participants. The MyVine study [28] examined when IM users wanted additional details about the state of colleagues over a simple scale of availability. Lilsys has added a level of control to the status information made available to others [5].

Here, I have tried to examine the privacy implications of a single predictive calendar system from a number of different perspectives. It is my intention that this thesis will provide guidance to developers and researchers who are working in the broader class of predictive groupware applications. For example, in both email and instant messaging, there are issues of control over potentially private content. In the case of instant messaging, there is also concern over one’s appearance to others as both a means of controlling access as well as presenting a desired impression to others. Efforts to add forecasting capabilities to these applications must account for similar issues of predictive integrity, consent, and notification.

Chapter 6: Reflections and future work

To conclude this thesis, I will discuss some of the lessons learned from building, deploying, and evaluating the Augur system. During the course of this work, I had to make a number of important design decisions with respect to the technologies used, methods employed, and information gathered. Many of these decisions were made in the interest of investigating a particular research issue; others were made to constrain the scope of the project or to accommodate the logistics of studying a moderately large group of study participants. The details of my design processes are described in the previous chapters of this thesis; in this section, I will examine some particularly challenging aspects of the project with an eye toward informing future efforts in this area. My motivation is to guide other researchers on how to potentially further the results I have presented.

6.1. Technological decisions

In this section I will examine some of Augur’s core technologies, reflecting on the decisions that prompted their development and briefly examining alternative or complementary technologies that may warrant further study.

6.1.1. Bayesian network models

Choice of Bayesian networks. Due to the uncertain nature of predicting event attendance, Bayesian networks were chosen for their ability to encode uncertain problems dependent on a number of related variables. Early in the design of the original Ambush system, the readability of Bayesian networks, as well as their ability to depict causal relationships, factored into their choice because I planned at the time to incorporate explanations into the Ambush/Augur interface.

Since the design of Augur, promising representations for the problem of availability[27] have shown that decision trees and support vectors can outperform human observers. Hill and Begole [44] developed an algorithm for detecting and predicting transitions in activity. These approaches have the benefit of taking a nearly pure machine learning approach, where user biases and inconsistencies are less of an issue. In addition, they use the data available to them rather than having users prescribe variables that the system may not be capable of sensing.

I believe it is important that whatever representation is chosen, it should have the ability to report either a probability or confidence measure. An uncertain problem requires a representation capable of handling uncertain output, and at the user interface level, designers should avoid giving users the impression that the system is completely confident in its ability to predict attendance. Therefore, binary representations of the problem are insufficient. Although Augur was ultimately not given the ability to generate explanations, given some of the diagnosing and privacy-management behaviors observed during the field study, I believe this feature to be important for future systems.

In addition, time-based representations may offer an improvement over Augur's networks. For example, the incorporation of dynamic Bayesian networks would allow for the inclusion of variable dependencies over time, providing a more up-to-the-minute prediction that could be updated continuously. Although considered for Augur, dynamic networks were not supported by the third-party modeling software and API used for the system.

Constructing networks. Interviews provided a way of modeling event attendance without relying on an existing set of historical data. Work on the Coordinate system [Horvitz] has demonstrated how Bayesian models similar to those of Augur can be generated automatically from a corpus of activity and presence history across a group of coworkers. This of course presumes the availability of such training data and some degree of behavioral similarity among members of a workgroup. This is an effective approach, and the challenge ahead lies in creating the initial models when the amount of training data is still low. Bootstrapping with models trained on other users shows promise, and the design of tools to create initial profiles is becoming an important task.

Eliciting models. Qualitative elicitation of models, similar to the methods used for Augur, are another avenue, but can be time-consuming and a burden on potential users. The elicitation of prior probabilities in the case of Augur's Bayesian networks was informal, with relative probabilities loosely described by users and encoded by the researchers. It was expected that over time, learning from attendance histories would improve and tune each model to its owner's particular attendance habits. As results showed, however, training data was sparse, and learning was hindered by exceptional events as well as academic term boundaries. Much more formal mechanisms exist for eliciting prior probabilities with a minimum of bias and higher reliability [96]. These methods have typically been developed for medical expert systems, but could easily be applied to the problem of event attendance. In the context of study, a more rigorous elicitation of prior probabilities would help to isolate sources of error and focus attention on external sources rather than the process that generated the models.

6.1.2. Sensing

As stated earlier, variables within the event attendance model had to be pared down due to Augur's inability to sense them. At the time, it was unknown how influential each variable would be in practice, and it was more important to study the system in use. Whether accurate or not, the impact of the system on communicative and social aspects of work would be novel and useful to future systems. Given the data generated by Augur, it would now be possible to perform a sensitivity analysis of models over time in order to determine which variables played the largest role in predicting attendance as compared to those reported by users at the start of the project. Such an analysis would be beneficial to future efforts at predicting event attendance.

New platforms such as Placelab [89] provide a low-cost infrastructure to perform location sensing. While I employed Placelab to create an attendance-logging component (see section 3.5.2.1), having location awareness across a workgroup would provide more details to models of attendance and potentially improve their accuracy.

An additional problem with Augur was that scheduled events such as seminars and group meetings were not examined for content to determine whether the owners who had scheduled them had a research interest in their topics. The ability to match event details and user interests would not only enable better attendance prediction, but possibly a recommendation aspect where users are made aware of events they may not have scheduled.

6.1.3. Attendance training data

Sparse or unrepresentative training data. As described in Chapter 4, the performance of Augur's attendance predictions suffered as a result of sparse training data as well as undesirable data that resulted from exceptional time periods such as spring break and finals week. In retrospect, it would not have been difficult to have anticipated these periods and discounted their training data.

In order to increase the system's knowledge of upcoming institutional events, it should be possible to incorporate institution-level calendars (e.g., school calendars, corporate event calendars) into context-aware systems. While anomalous in terms of day-to-day behaviors, these events are predictable to users familiar with the institution. In the case of Augur, knowledge of the school and departmental calendars would have provided context to both adjust predictions and discount training data obtained during exceptional events.

To obtain more training data, low-cost automated techniques exist for determining attendance, such as matching idle times at a user's workstation with scheduled calendar events.

6.1.4. Event classification

Event variety and diverse calendaring habits. Efforts aimed at classifying events by attributes such as type and location were hampered by the variety inherent in the calendar descriptions of field study participants. Descriptions were often too terse or ambiguous to learn their meaning. In retrospect, although it provided more training data, attempting to train classifiers across all participants was not ideal. Even though participants were from the same academic department and for the most part in the same building, even scheduled institutional events differed significantly, and personal event descriptions varied from person to person.

In general, when attempting to determine event-level attributes, the more individualized the technique, the better. When the amount of available training data is an issue, a compromise may be to train at the level of a small workgroup, which was effective for some classes of events in Augur pilot studies. However, the most accuracy will be gained from training on users individually, whether it is done through an initial setup step, or through a mixed-initiative approach that prompts users for more information when confidence in the classifiers are low.

6.1.5. User interface

Barriers to use. During the field study, two participants ceased using the system after encountering several barriers to use. Simple changes such as giving the Augur site a easy-to-remember URL would have potentially prevented this from happening. In addition, browser problems with accepting cookies meant that for some participants, their login information was not remembered, requiring them to re-enter their usernames and passwords. Overall, the experience of using Augur was somewhat difficult for some, and potential users were lost due to issues unrelated to the intended functions of the system.

Existing interface versus new interface. While not possible given the heterogeneous calendar artifacts of the deployment site, an existing, adopted calendar interface would have provided more instances of use than the web-based interface created for Augur. This UI lacked a number of features that are taken for granted in most calendar applications, such as week/month views, meeting scheduling, and reminders. While some of these features were present on users' existing artifacts, no interface contained both these features and Augur's predictions.

Displaying accesses. The original version of Augur included a counter to show how many times a particular event had been viewed by others. This was removed for the field study for fear it would make a novel UI even more confusing. In retrospect, participants typically estimated that fewer people were viewing their events than was the case. Giving them the ability to see that their calendars were in fact being viewed may have encouraged many of the maintenance behaviors that were so sparsely observed during the study. Future CMC or awareness prototypes should consider such a feature, especially where privacy or impression management are concerned.

Mobile Augur. A motivation for Augur was to allow calendars to remain useful tools in the face of increased worker mobility. While making Augur web-accessible was a priority, incorporating a mobile version of the interface was also of interest since many participants reported referring to their calendars more frequently when mobile. While some efforts were made at creating a PalmOS-based attendance diary, a mobile version of Augur was never built. Given that most users did not synchronize their devices more than once a week, it would be difficult for a mobile version of Augur to have updated calendar and predictive information. Such an application seems more feasible on a Wi-fi or Bluetooth-enabled device, but unfortunately most participants did not have such capabilities on their PDAs. In addition, the prospect of enabling Augur on mobile phones was too daunting given the variety of phones used by participants.

6.2. Methodological decisions

In addition to technological choices, the design of the Augur field study required a number of decisions with respect to its participants, location, and data-gathering methods employed. Here I will review how these decisions benefited or hindered research, and what alternatives were possible.

6.2.1. Site

As discussed in Chapter 4, I chose an academic setting for the Augur field study due to an existing familiarity with work practices and events as well as a system that was designed around this environment's work practices. While less time was needed to perform ethnographic study of the work environment, learning about work relationships and communication practices, there were certainly elements of the academic environment that made the study more difficult. For instance, the heterogeneity of calendar artifacts across participants meant that no existing interface could be augmented to incorporate Augur's predictions; therefore, a new web-based version had to be created.

As noted earlier, use of Augur was only sporadic in the academic setting. Had a stronger work culture existed around a chosen calendar application, as in many industrial settings, more instances of use would likely have been recorded. In addition, adoption issues would be less of an issue in an established infrastructure, enabling more focused attention on practices. An industrial deployment is discussed later in the future work section.

6.2.2. Scope

Design scope. The version of Augur deployed in the semester-long field study was a realization of my early vision for a forecasting groupware calendar. This vision consisted of an application that could display, at a glance, the set of colleagues that a person was likely to see on a given day. After the field study, it became clear that error propagation between the predictive elements of Augur significantly degraded overall performance. The features of Augur could be studied individually as smaller augmentations to existing applications rather than housing them all under a single interface. In other words, event matching could be deployed separately from attendance prediction to different populations in order to reduce error rates and perhaps learn the relative utilities of each feature before combining them. Such a study would benefit the design of each individual component, especially in terms of quantitative accuracy. For the purposes of my thesis, however, the two features were designed to work in tandem to address specific goals of finding people for “ambushes” and other informal meetings.

Deployment scope. While predictions suffered in part from a greater diversity of calendar data in the field study, pilot studies on a smaller group of less than ten people reported better results in classifying events due to a more constrained vocabulary of work-related events. I believe this shared vocabulary of events within smaller groups could be exploited further to generate even better results in terms of predictive accuracy. Reflecting on the study of Augur, the design process and ultimate realization of the system seemed better suited to deployment within small groups, as early pilot studies on a small group seemed to function more effectively than the larger field study. Depending on the independence of workgroups, separate Augur deployments to smaller groups may be a preferred means of initiating the system as opposed to a single large-scale installation, allowing for more specific training on each group. A qualitative study of Augur similar to that used for the larger-scale field study could be conducted on a small group to prove or disprove this claim.

6.2.3. Interviews

Semi-structured interviews provided a means of learning about system use and gaining additional details about the context in which the use occurred. However, interviews were spaced apart by several weeks, so participants had some difficulty recalling specific instances of use.

Two alternatives may have increased the fidelity of this data. First, a diary study would allow participants to detail use of the system on the same day it occurred, presumably allowing for a more descriptive record. Experience sampling (ESM) would also perform a similar function, getting the context of system use as it happens. However, both of these techniques require more work on the part of the participant. ESM in particular can be seen as a nuisance if employed too frequently. In the case of Augur, use was sparse, so a context-triggered ESM study would be a possibility [52]. A diary study, however, may have provided additional information for interviews that would have allowed a more detailed analysis of effects on practices.

Second, providing more context to interviews by investigating Augur's system logs beforehand may have helped in jogging the memories of participants. This technique was not used primarily because I worried about making participants uncomfortable by revealing how much I knew about their calendars and use of the system. However, a compromise may be to reveal a specific date/time of use without going into the details of what occurred, letting the participant fill in the blanks.

6.3. Future work

The previous section detailed how various aspects of the Augur project could be improved or reformulated to better investigate the research questions explored in this thesis. This section will examine broader future paths for research in intelligent groupware, focusing in particular on issues of trust and control.

6.3.1. Industrial deployment

Overall, the design of Augur was fairly ambitious. While introducing groupware is difficult for numerous reasons [38], the addition of predictive features presents further challenges in terms of encouraging use and adoption. Ideally, Augur's features would be smoothly integrated with an existing, adopted groupware calendar system. While an academic environment offered many advantages, a more focused study of the core predictive features of Augur would perhaps be better obtained by an industrial deployment where groupware tools are more standardized. The software used would not be the Augur application as presented in this thesis, but a set of Augur-like features overlayed onto a commercial application such as Outlook or Notes. In order to observe changes in communication practices, a fair amount of advance ethnographic work would need to be performed to understand the specific practices, relationships, and social norms of the study site. However, the ethnographic work on calendars cited in Chapter 2 would help to shorten this time in that these prior studies identify broader behaviors found in industrial settings.

6.3.2. Balance accuracy with control

An interesting issue with forecasting groupware systems is the degree to which they should faithfully represent a person's true status. Much effort has been expended in designing, building, and refining various representations of activity, availability, and presence to achieve the most accurate forecasts to the user activity that actually transpires (see section 2.2.3). For work-related tasks such as informal communication, meeting scheduling, and remote collaboration, accurate information is key to their success. A system that tends to be incorrect for even a small percentage of cases will still be neglected by users if the work being accomplished is sufficiently critical.

At odds with these research efforts, however, are user behaviors intended to protect privacy or convey a particular impression within the workplace. We have already seen how users in previous ethnographic work [81] as well as participants in the field study outlined in Chapter 4 used omissions and fake appointments to control access. In addition, there was some evidence in the field study, as well as work by Beard *et al*. [3], that shared predictions of attendance can have a negative effect on the impression users want to convey even if they are accurate.

An understanding of when users choose to share accurate predictions and when they opt to override them would be useful to designers who must complement accurate user models with the design of control mechanisms to support social objectives. Studies of how users manage their image through email [94] and instant messaging can contribute to this understanding.

6.3.3. Understanding predictions: mental models

Without adequate knowledge of how a system like Augur generates its predictions, the possibility of restoring users' control over their personal information becomes unlikely. The literature on forecasting groupware systems has to this point only begun to examine these kinds of concerns. I posit that a better understanding of users' mental models of such systems will aid in designing effective controls for managing the predictions they generate.

Mental models are a fundamental concept in HCI, but encompass a much broader spectrum of theory on human cognition. Norman gives a straightforward definition of mental models [80]:

> In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction.

Given the novelty of systems like Augur, insufficient experience exists for most users to develop folk theories of its predictive features or acquire them from others. However, users are likely to have existing methods of obtaining the information such systems are trying to predict. In this sense, an understanding of these existing methods serves as a first clue to how users may expect a predictive system to behave.

Moray's theories on mental models as homomorphisms [75] are key to the design of intelligent groupware. The degree to which users develop reduced conceptualizations of the actual system model is dictated by the state which is made visible to them, the task to which the system is applied, and the duration for which the system has been used.

6.3.3.1. Preliminary study: mental models of Augur

In August 2004 a questionnaire was distributed to ten participants in the Augur field study described in Chapter 4. The questionnaire was designed to elicit respondents' mental models of two features: Augur's attendance prediction capabilities and its ability to match events across user calendars. Appendix D lists the questionnaire.

Respondents almost uniformly gave overly simple descriptions of how Augur generates attendance predictions and overly complex descriptions of how it matches events across user calendars. While all users correctly associated the attendance form with its role in training attendance predictions, few recognized that event attributes such as type and location were used in the prediction, and only two correctly assumed the use of conditional probabilities. In contrast, half of the respondents incorrectly assumed Augur uses recurrence to match events and three believed the matching was related to event attendance.

The reason for this disparity may be related to the feedback and controls currently provided by Augur. The only inputs available to users are their calendars and attendance information. It is reasonable to assume that attendance predictions are based on a simpler heuristic that associates an event name with a score based on past attendance as suggested by several participants. For the event-matching feature, users have only one implicit input, their calendars. There was no explicit link between calendar input and the output of the event matching module.

From another perspective, the event-matching feature was the more error-prone of the two predictive mechanisms during the field study. Inaccuracies were easy for users to see and were cited more frequently than inaccurate attendance predictions. It is possible that in the absence of a predictable pattern to the errors, participants had to resort to more complicated explanations for the system's behavior. In contrast, attendance predictions that were regarded as reasonable allowed participants to form simpler models.

6.3.4. Feedback

One drawback of the Augur system is that there is little explanatory feedback designed into the system itself. Thus, the mental models formed by users of Augur can only be confirmed or rejected through trial-and-error experimentation. Although people have a notoriously difficult time solving even the most simple Bayesian reasoning problems [56], a great deal of work has been performed in terms of understanding the reasoning of

Bayesian networks. Explanation systems, both graphical [17, 66] and verbal [43, 92] have been developed to improve the lay user's conceptual model of such networks. Lastly, visibility of system inputs and inference will allow users to better manage their privacy through the application.

6.3.5. Designing controls for forecasting groupware

Future controls for managing shared information in forecasting groupware can be guided by a number of dimensions related to the system being designed. These dimensions are outlined in Table 6-1 and Table 6-2.

At the system level, user information can be gathered from one source, or several information sources may be aggregated, as in a system like Augur. This information may have varying degrees of accessibility to the user. For instance, a user may have complete, fine control over the contents of her online web page, but less control over archives of her old newsgroup postings or indirect social connections to other people. Intelligent systems that act as "black box" generators of inferences or decisions present the most difficult barriers to user control due to their more complex system models. In addition, the mechanisms used to process the information may be more or less complex.

Table 6-1: System dimensions affecting impression management.

Dimension	Description	Example	
Number of inputs	The variety and amount of personal information used by the system.	Many: Few:	Fogarty *et al* [50] Instant messenger status
Number of outputs	The number of components comprising the machine-generated persona.	Many: Few:	Augur Instant messenger status
Accessibility of inputs	Ease with which users can control the information used by the system.	Accessible: Less Accessible:	Calendar events A/V sensors
Complexity of algorithm	Complexity of the process which transforms personal information into a shared persona.	Simple: Complex:	Basic open-access calendar Augur

With respect to users, information may be publicly available, such as a mailing list membership, or it may be more private, such as calendar information. Users may be more or less collocated, affecting whether issues of shared information are addressed through technological or social means. For example, users that are collocated can rely on frequent social interaction to overcome confusion arising from information that is shared online. However, users that collaborate remotely may come to rely on this shared information to accurately represent a coworker.

Table 6-2: User dimensions affecting impression management.

Dimension	Description	Effects
Privacy preferences	User's attitude toward what information should be shared and what should be kept private.	May impose restrictions on use of personal information and thus permit a less rich persona.
Collocatedness	To what degree a user is geographically near her colleagues.	Collocated users may rely more on social norms to resolve issues concerning persona.

Dimension	Description	Effects
Frequency of interaction	To what degree a user interacts with her colleagues in the workplace.	Coworkers with little interaction may rely more on technological means of persona management.

Together, these dimensions may represent the beginnings of a design space for employing controls for predictions in forecasting groupware. Management strategies may include technical or social solutions, or both (

Table 6-3). As a non-technical solution, users may simply develop new social norms around the technology. In the simplest technical solution, users are provided with a group of individually managed settings that provide control over the disclosure and manipulation of their personal information. Users may be able to discern a system's algorithms by "gaming" it through trial-and-error, provided the algorithm is not overly complex and its inputs are known. Designers can also give systems the ability to learn user preferences over time. Some systems even allow direct editing of the rules learned or the model built [74]. Finally, users may also manipulate the system's output directly, such as with custom status messages in many instant messaging clients.

Overall, by examining the strategies employed by users of various systems, as well as the particular attributes of those users and systems, a taxonomy of management strategies can be devised that allows designers to inform the support provided in future systems.

Table 6-3: Overview of management strategies.

Strategy	Description	Example
Social norms	Users develop new social practices to deal with a shared artifact.	Plausible deniability of instant messenger response.

Strategy	Description	Example
Preferences	Users configure settings that control how their information is gathered and used.	Access-control lists, privacy settings in shared calendars.
Gaming	Trial-and-error manipulation of inputs eventually results in learning a working conceptual model of the system.	Using particular keywords in email to boost its priority.
Learning	Preferences are learned over time by unsupervised or example-based techniques.	Automatic scheduling systems for shared calendars.
Editing of output	The system's output is edited directly by the user to a desired state. Changes are possibly fed back into the system's user model.	Customized status information on instant messaging clients.

6.4. Long-term agenda

Looking toward the future of my research career, I see the potential for intelligent systems to become pervasive in everyday group applications. I will continue to design and construct novel group support applications that incorporate intelligence, and to study these technologies in real-world environments as a means of understanding the costs and benefits they present to users. Additionally, I hope to develop techniques for enabling user control in these systems so that people may benefit from such applications without needing to continually manage what is inferred about them.

6.5. Conclusions

In this document, I have presented research efforts aimed at demonstrating the following thesis statement:

A groupware calendar system augmented with predictive models of user attendance will enhance calendar-based practices, and evaluation of this system will

lend insights about the effects of the broader class of forecasting groupware on communication and social factors.

Chapter 1 describes how predictive models are being considered as a feasible solution to the problem of facilitating communication and coordination in an increasingly mobile workplace with high demands on user attention. In addition, it cites the groupware calendar as a representative example of how such models can be incorporated into common applications.

Chapter 2 outlines the state of the art in forecasting groupware applications, establishing them as a new class of systems that includes the calendar application central to this thesis. Reviewing the literature on these applications also demonstrates the need for studies of how these systems affect practices, social environments, and working relationships. It also presents what is currently known about the adoption and use of shared calendars in the workplace, drawing upon ethnographic work to inform the design of a new calendar system that better supports the practices they report.

Chapter 3 describes the design and implementation of Augur, a groupware calendar system augmented with predictive models of user attendance. It builds on the background of Chapter 2 to describe the architecture, user model, and user interface of a novel system for enabling communication and coordination through shared calendars.

Chapter 4 presents a field study of Augur conducted on an academic workgroup. The study demonstrates that while Augur did not become a primary option for coordinating informal communication, it was used as a support application when existing, preferred methods failed. In addition, the system was appropriated for social calendar browsing as well as maintenance tasks associated with managing Augur’s predictions. Further, use of

Augur's predictions for coordinating communication occurred more frequently for close and moderately close colleagues with limited schedule knowledge of one another, indicating that the system was best suited to their needs.

Chapter 5 analyzes Augur for high-level privacy vulnerabilities in the achievement of user and system goals. The results show that predictive integrity is a concern for users and has the potential to misrepresent users if appropriate controls, notifications, and consent are not provided. Moreover, these results generalize to the broader class of forecasting groupware applications that provide and share similar predictive information.

Overall, I believe this thesis verifies the above statement. Augur does enhance calendar practices such as finding, scheduling, and orienting, but it is inconclusive from the results of this work that these enhancements outweigh the costs of maintaining the additional predictive information. Therefore, the *benefit* is still unclear. In addition, I believe I have shown that the social issues inherent in Augur's use of inference are concerns for the broader class of forecasting groupware applications to which Augur belongs.

Appendix A: Calendar use survey

1. Title (check one):

   ( ) Dean/Assistant Dean

   ( ) Professor

   ( ) Administrative assistant

   ( ) Ph.D. student

   ( ) M.S. student

   ( ) Undergraduate

2. Area (e.g., Theory, Graphics, HCI, etc.)

   ____

3. How do you keep track of your schedule (check all that apply)?

   ( ) In my head

   ( ) I email notes to myself

   ( ) I put paper notes/post-its around my office

   ( ) I use a paper calendar

   ( ) I use an electronic calendar

   ( ) Other: _______________

   If you use an electronic calendar, which one (check all that apply)?

      ( ) Palm/Palm Desktop

      ( ) Outlook

( ) Notes

( ) Yahoo calendar

( ) Corporate Time

( ) iCal

( ) Evolution/Mozilla/JiCal

( ) Other: _______________

4. If you use a calendar, what type(s) of entries are on it (check all that apply)?

( ) Professional events (courses, seminars, meetings, etc.)

( ) Activities (sports, hobbies, student organizations, etc.)

( ) Personal (dinner, movies, parties, etc.)

( ) Holidays (birthdays, anniversaries, etc.)

( ) Tasks/to-do items

( ) Private events

5. With whom do you share your calendar (check all that apply)?

Friends

Acquaintances	( ) some	( ) all
Close friends	( ) some	( ) all

Family

Spouse/significant other	( ) some	( ) all
Immediate family	( ) some	( ) all

Extended family	( ) some	( ) all

Colleagues

Boss(es)	( ) some	( ) all
Coworkers (same level)	( ) some	( ) all
Subordinates	( ) some	( ) all

General Public	( ) all

6. If you keep a calendar, do you share it?

( ) yes

( ) no

If so, how (check all that apply)?

( ) I email my schedule to people

( ) I hand-copy items to other calendars

( ) I publish it on the Web

( ) I keep it in a .plan file

( ) I put paper copies on my door, desk, or walls,
or I distribute them to people

( ) I use a server (e.g., Microsoft Exchange, Notes)

( ) Other: _______________

7. How do you control access to your calendar (check all that apply)?

( ) I tell select people where it is

( ) I phrase the entries so they only make sense to certain people

( ) I have an access-control list or password protection

( ) I mark private events so no one can read them

( ) Other_______________________________

8. a) Do you ever view the schedules of others?

( ) yes

( ) no

How (check all that apply)?

( ) Unix finger

( ) Web calendar (e.g., Yahoo)

( ) Posted on door

( ) Server (e.g., Microsoft Exchange, Notes)

( ) Other: ________________

b) Please describe a situation where you needed to know another person's schedule. Why did you need to see it? How did you find the schedule?

9. Do you own a PDA?

( ) yes

( ) no

If yes, what type (check all that apply)?

( ) PalmOS (Treo, Visor, Pilot, Tungsten, Clie, e.g.)

( ) PocketPC (IPAQ, Jornada, e.g.)

( ) Windows CE (Nino, older IPAQs and Jornadas, e.g.)

( ) EPOC (Psion, e.g.)

( ) Other _______________

10. If you own a PDA, how often do you synchronize it to a PC?

( ) daily/multiple times a day

( ) every few days

( ) weekly

( ) semiweekly/monthly

( ) never

Appendix B: Field study interview questions

B.1. Preliminary questions

Demographics

Age: ___

Gender: M / F

Occupation: (Student / Faculty / Staff)

Area: ____________

Advisor (if applicable): ___________

Years at Georgia Tech: ___________

Current Work Practices

How did you previously keep track of your schedule (check all that apply)?

( ) In my head

( ) I email notes to myself

( ) I put paper notes/post-its around my office

( ) I use a paper calendar

( ) I use an electronic calendar

( ) Other: _______________

If you used an electronic calendar, which one (check all that apply)?

( ) Palm/Palm Desktop

( ) Outlook

( ) Notes

( ) Yahoo calendar

( ) Corporate Time

( ) iCal

( ) Evolution/Mozilla/JiCal

( ) Other: _______________

What type(s) of entries are on your calendar (check all that apply)?

( ) Professional events (courses, seminars, meetings, etc.)

( ) Activities (sports, hobbies, student organizations, etc.)

( ) Personal (dinner, movies, parties, etc.)

( ) Holidays (birthdays, anniversaries, etc.)

( ) Tasks/to-do items

( ) Private events

If you keep a calendar, do you share it?

( ) yes

( ) no

If so, how (check all that apply)?

( ) I email my schedule to people

( ) I hand-copy items to other calendars

( ) I publish it on the Web

( ) I keep it in a .plan file

( ) I put paper copies on my door, desk, or walls, or I distribute them to people

( ) I use a server (e.g., Microsoft Exchange, Notes)

( ) Other: _______________

With whom did you share your calendar (check all that apply)?

Friends

Acquaintances	( ) some	( ) all
Close friends	( ) some	( ) all

Family

Spouse/significant other	( ) some	( ) all
Immediate family	( ) some	( ) all
Extended family	( ) some	( ) all

Colleagues

Boss(es)	( ) some	( ) all
Coworkers (same level)	( ) some	( ) all
Subordinates	( ) some	( ) all

General Public ( ) all

How do you control access to your calendar (check all that apply)?

( ) I tell select people where it is

( ) I phrase the entries so they only make sense to certain people

( ) I have an access-control list or password protection

( ) I mark private events so no one can read them

( ) Other______________________________

a) Do you ever view the schedules of others?

( ) yes

( ) no

How (check all that apply)?

( ) Unix finger

( ) Web calendar (e.g., Yahoo)

( ) Posted on door

( ) Server (e.g., Microsoft Exchange, Notes)

( ) Other: ________________

What is your primary purpose in browsing another person's schedule?

How do you typically coordinate informal meetings with your advisor/superior? With colleagues?

How do you typically coordinate social meetings with friends/colleagues?

Do you own a PDA?

( ) yes

( ) no

If yes, what type (check all that apply)?

( ) PalmOS (Treo, Visor, Pilot, Tungsten, Clie, e.g.)

( ) PocketPC (IPAQ, Jornada, e.g.)

( ) Windows CE (Nino, older IPAQs and Jornadas, e.g.)

( ) EPOC (Psion, e.g.)

( ) Other _______________

Did you previously synchronize your PDA less than once a week?

<u>Privacy/Image through calendar</u>

How do you protect private calendar information?

( ) I omit it from my shared calendar

( ) I word the descriptions such that no one else can understand them

( ) I control who has access to the calendar using permissions

( ) I maintain different calendars for different people

( ) Other ways:

What factors determine whether someone gets access?

Rate how you feel about each of the following potential concerns with calendar sharing on a scale of 1-7, with 1 being “Very comfortable” and 7 being “Very uncomfortable”:

	Friends	Family	Colleagues	Superiors	Strangers
Viewing my personal appointments					
Inferring my location throughout the day					
Inferring who I am with throughout the day					
Inferring what I am working on throughout the day					
inferring how busy I am throughout the day					

<u>Expectations</u>

In what ways do you expect Augur to benefit you?

What are the three greatest benefits about your current method of handling schedules?

What are the three biggest problems?

B.2. Interview questions during Augur deployment

Practices

How many unplanned meetings would you say you had last week? Can you remember how they were facilitated?

Talk about your use of the system over the last week.

- When you view your own schedule, what activities do you perform? (Orienting, Setting up meetings, Other uses?) Proportions?

- When you view others' schedules, what activities do you perform? (Exploring others' calendars, Setting up meetings, Other uses?) Proportions?

Has anyone mentioned viewing your calendar? Why were they doing it? Did they mention the predictions?

Please relate any surprises you have encountered in terms of viewing others' schedules or hearing from others who have viewed your schedule. Include thoughts on predictions.

Since you started using Augur:

Now that your calendar is shared:

Do you name your events more clearly/less clearly/the same?

Do you include more/less/the same amount of detail?

Do you sync your calendar more/less often?

Have you taken any actions to try to change the predictions or other attendees that Augur displays?

This includes diligence in filling out attendance diary – influences predictions

Privacy/persona

Rate how you feel about each of the following potential concerns with calendar sharing on a scale of 1-7, with 1 being “Very uncomfortable” and 7 being “Very comfortable”:

	Friends	Family	Colleagues	Superiors	Strangers
Viewing my personal appointments					
Inferring my location throughout the day					
Inferring who I am with throughout the day					
Inferring what I am working on throughout the day					
Inferring how busy I am throughout the day					

Colleague ___________

Collocatedness:

Describe the work week for each of you?

Interaction frequency:

Describe some ways in which you would coordinate a planned (scheduled) meeting with this person.

Describe some ways in which you would coordinate an unplanned meeting with this person.

What information about this person's schedule do you keep in your head? For what information do you resort to external sources?

Rank the following tools in terms of how often you initiate/coordinate ***unplanned meetings*** with this colleague:

___Augur	___Email
___Drop in	___Other calendar
___Phone	___Other___________
___Ask a third party about this person's schedule	___Other___________
___IM	___Other___________

I know enough about this person's schedule to coordinate *unplanned meetings* when needed.	1 Strongly Disagree	2	3	4	5 Strongly Agree
I know enough about this person's schedule to coordinate *planned meetings* when needed.	1 Strongly Disagree	2	3	4	5 Strongly Agree
I know enough about this person's schedule for the work we perform together.	1 Strongly Disagree	2	3	4	5 Strongly Agree

Trust/reliability

In this section, you will be asked to rate a computer's ability to predict your schedule. Initially, you will have no information on which to base your ratings, so it will be a subjective estimate. Later in the study, you will see actual predictions and make your ratings based on them.

Questions about your own calendar:

To what extent can your attendance at *one-on-one meetings* be predicted?	1 Not at all	2	3	4	5	6	7	8	9	10 Completely
To what extent can your attendance at *group meetings* be predicted?	1 Not at all	2	3	4	5	6	7	8	9	10 Completely
To what extent can your attendance at *classes* be predicted?	1 Not at all	2	3	4	5	6	7	8	9	10 Completely
To what extent can your attendance at *seminars* be predicted?	1 Not at all	2	3	4	5	6	7	8	9	10 Completely
To what extent can your decision to attend one of two conflicting events be predicted?	1 Not at all	2	3	4	5	6	7	8	9	10 Completely
Overall, how much do you trust the system to predict your schedule accurately?	1 Not at all	2	3	4	5	6	7	8	9	10 Completely

Colleague: ______________

How reliable is this colleague's schedule generally?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely
To what extent this colleague's attendance at *one-on-one meetings* be predicted?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely
To what extent can this colleague's attendance at *group meetings* be predicted?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely
To what extent can this colleague's attendance at *classes* be predicted?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely
To what extent can this colleague's attendance at *seminars* be predicted?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely
To what extent can this colleague's decision to attend one of two conflicting events be predicted?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely

Colleague: _____________

How reliable is this colleague's schedule generally?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely
To what extent this colleague's attendance at *one-on-one meetings* be predicted?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely
To what extent can this colleague's attendance at *group*	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all Completely

meetings be predicted?	
To what extent can this colleague's attendance at *classes* be predicted?	1 2 3 4 5 6 7 8 9 10 Not at all Completely
To what extent can this colleague's attendance at *seminars* be predicted?	1 2 3 4 5 6 7 8 9 10 Not at all Completely
To what extent can this colleague's decision to attend one of two conflicting events be predicted?	1 2 3 4 5 6 7 8 9 10 Not at all Completely

Colleague: ______________

How reliable is this colleague's schedule generally?	1 2 3 4 5 6 7 8 9 10 Not at all Completely
To what extent this colleague's attendance at *one-on-one meetings* be predicted?	1 2 3 4 5 6 7 8 9 10 Not at all Completely
To what extent can this colleague's attendance at *group meetings* be predicted?	1 2 3 4 5 6 7 8 9 10 Not at all Completely
To what extent can this colleague's attendance at *classes* be predicted?	1 2 3 4 5 6 7 8 9 10 Not at all Completely
To what extent can this colleague's attendance at *seminars* be	1 2 3 4 5 6 7 8 9 10 Not at all Completely

predicted?	
To what extent can this colleague's decision to attend one of two conflicting events be predicted?	1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 Not at all … Completely

Appendix C: Description for privacy analysis study

Introduction

Augur is a shared calendar system designed to help a group of colleagues communicate. Calendars are often used as tools for assessing someone's availability or location, but they require maintenance to remain accurate. For instance, a person may not attend all the events he schedules, or he may schedule events that conflict one another. A student may have stopped attending a particular class or seminar even though those events remain on her calendar. Problems like these make a calendar less useful for the communication tasks it typically supports, such as finding particular colleagues or scheduling time with them.

Augur is a web-based, shared calendar that provides additional predictive features intended to facilitate communication within a workgroup. These features include predictions on the attendance of colleagues at future events, as well as predictions on who has scheduled the same events. These predictions improve over time by learning from past attendance patterns. With these features, users can identify events that are no longer attended, make informed decisions about which of several conflicting events will be attended, and determine who they will likely see at a particular event.

Interface

Users access Augur by opening the Augur URL in their browser and securely logging in. To ease the login process, Augur is capable of automatically logging in users from a particular computer. Once logged in, users are presented with a welcome screen allowing them to navigate to their calendar for particular day.

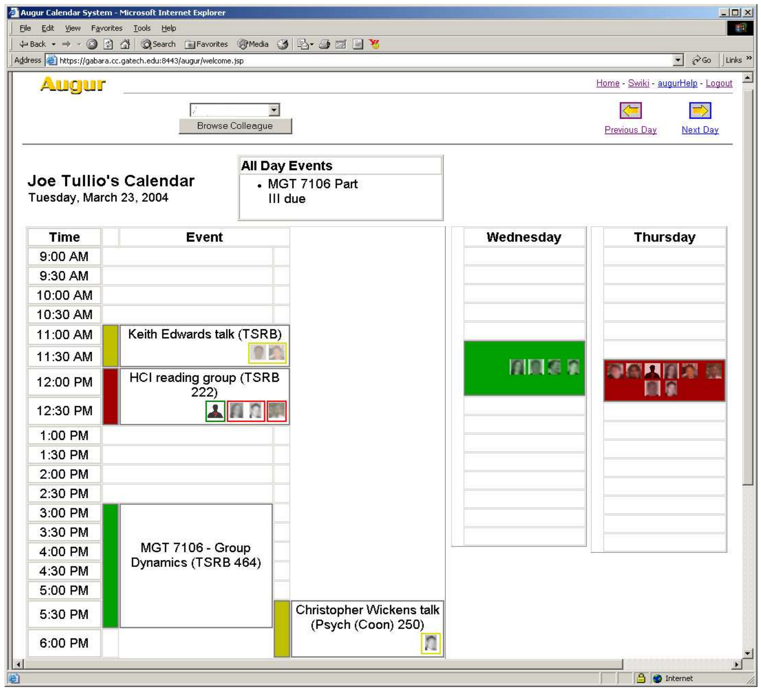


Figure 1: Augur user interface.

Augur presents a user's scheduled events for a day in an hour-by-hour, block format that is similar to the tabular style used by other calendar systems (iCal, Outlook, Mozilla Thunderbird, etc.). However, this view is augmented with additional information that indicates colleagues who have scheduled the same events and attendance probabilities for colleagues at those events. Figure 1 shows a screenshot of Augur. The events on a user's calendar are augmented with a list of icons that indicate which of the user's colleagues have also scheduled the event. Each icon represents a particular colleague, and a colleague's icon is displayed within an event on the calendar if the colleague has also scheduled that event. In the calendar shown in Figure 1, the user can see that four other colleagues have co-scheduled the ‘HCI reading group' event on their calendars. Icons are arranged in decreasing likelihood of attendance from left-to-right. Colleague icons are clustered in an event based on their attendance likelihood using colored boxes; the color of the box around an icon group indicates the attendance likelihood of the colleagues in that box. For example, a bright green box surrounds colleagues' icons that are very likely to attend the event. The color groups are bright green, green, yellow, red, bright red in descending order of attendance likelihood.

Events on a user’s calendar also have a colored bar to their left that indicates the user’s likelihood of attendance at that event based on Augur’s predictive models. The color scheme used for this bar is identical to that used for the colleague icons described earlier.

To the right of the daily calendar are visualizations of the worker's calendar for the next two days, which we call 'bar calendars'. Note that the bar calendar does not display the events' descriptions. Event blocks in the bar calendars are colored to indicate the overall popularity of an event; again, a green, yellow, and red color palette is used to color the bar calendar's event blocks. An event's popularity is sum of the attendance probabilities of all colleagues who have scheduled the event. Hence, events where the worker is likely to see many colleagues are colored green, events where the worker is likely to see a few colleagues are colored yellow, and events where the worker is unlikely to see any colleagues are colored red. As in the daily calendar, we place icons in bar calendar event blocks to indicate which colleagues also have scheduled events that are on the user's schedule. Again, left-to-right ordering is used to indicate the likelihood that a colleague will attend an event.

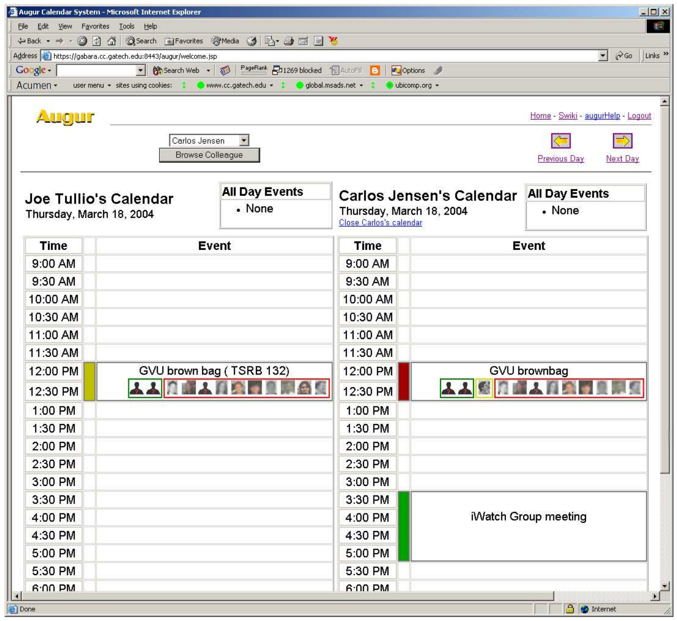


Figure 2: Augur interface with side-by-side calendars.

The user can also interact with the calendar to obtain more information about his colleagues' calendars. When the user mouses over an icon on his daily calendar, a menu pops up. This menu identifies the colleague using his name and a small picture, indicates how likely the colleague is to attend the event, and provides a hyperlink to the colleague's calendar. When the user clicks on the hyperlink, an animation shrinks the user's calendar, hides the user's bar calendars, and displays the colleague's calendar to the right of the user's daily calendar (Figure 2). This allows the user to easily compare schedules and plan communication with the colleague accordingly. Note that the colored bars to the left of events on the colleague's calendar are predictions of attendance for that colleague.

Augur system description

The Augur system consists of a number of components that process, store, and serve calendar information located in a central relational database. It retrieves user calendar data from other calendar systems such as Palm Desktop and iCal, augments the data with information about attendance likelihood and events co-scheduled by colleagues, and serves that information to the web-based user interface.

To obtain calendar information, Augur contains software that allows it to use existing calendar data from other calendar systems. For example, Augur contains PalmOS conduit software that automatically sends calendar information to our parsing module when a PalmOS PDA is synchronized with a networked computer. For iCal and Mozilla Thunderbird users, we have web-based tools that will automatically update Augur upon changes to calendar data. The parsing module reads the formats of these external calendars and updates a table of events in the central database with this information.

Once the latest calendar data is retrieved, our prediction and event matching modules insert additional information into the database. The prediction module uses a Bayesian network to add information about the likelihood of attendance for future events. Each user is associated with a separate copy of the network that is capable of learning their individual attendance habits over time. An additional component allows users to provide examples to the system by submitting daily attendance checklists via the web. The event-matching module uses text-processing techniques to identify events from other colleagues' calendars that are likely to represent the same event.

With current, augmented calendar data now present in the database, web-based visualizations display this information to users through the user interface. The daily calendar view, described previously, displays a user’s scheduled events along with information about whom he/she might see at those events. Additional software logs accesses to the visualizations and stores this information in the database, but is currently only used for the purposes of scientific study.

Appendix D: Mental models questionnaire

Background

Please answer the following questions to the best of your ability. If you can't remember a particular piece of information, feel free to give a rough approximation.

Please list any courses you have taken in artificial intelligence or machine learning, and when you took them.

Please describe any other experiences you have had with machine learning or intelligent systems and when they occurred. Include relevant talks you have attended or papers that you have read.

Have you read any research papers on the Augur system? Please list which papers and when you read them, if you can remember.

Have you attended any presentations, poster sessions, or talks concerning Augur? When did you attend them? Please include any conversations with the investigator(s) about how Augur works.

Questions

Please answer the following questions *without referring to any other documents or web pages*. When possible, describe why you believe your answers to be true.

The following questions will ask you about the attendance prediction features in Augur.

Please describe how you think Augur generates predictions of attendance at events for its users. Include what information you think it uses as input, what kind of reasoning is performed on that information, and what form the output takes.

Feel free to include a diagram if possible.

Does Augur learn from past or current information to inform future attendance predictions? If so, what does it learn from, and when does the learning occur?

How can a user change the attendance predictions that Augur makes?

Under what circumstances does this feature tend to provide more accurate predictions? When do the predictions tend to be less accurate?

The following questions will concern Augur's ability to identify which colleagues have scheduled the same events.

Now, please describe how you think Augur determines which users have scheduled the same events. Include what information about the users and their calendars you think is used as input. How is this information then used to match events across user calendars?

Feel free to include a diagram if possible.

Does Augur use past or current information to inform future inferences about which users' events match across calendars? When does it learn and how?

Under what circumstances does this feature tend to accurately match events? When are the matches less accurate?

Please rate your agreement with the following statements on a scale of 1 to 7, where 1 is "Strongly Agree" and 7 is "Strongly disagree".

___ I believe I have a pretty good idea how Augur predicts attendance at future events.

___ A system like Augur can learn to predict attendance accurately over time

___ I believe I have a pretty good idea how Augur predicts which people have scheduled the same events.

___ A system like Augur can learn to predict which people have scheduled the same events accurately over time.

___ Systems like Augur will tend to fail because of the kind of reasoning and learning they are doing.

___ People will have trouble accepting these systems because it isn't clear how they work.

___ When using Augur, it was easy to discover how the system made its predictions.

___ It was easy to learn how to change Augur's predictions by manipulating the information it uses.

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